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ABSTRACT

A summary of the proceedings of the conference of experts convened by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and by the International Union of Geological Sciences introduces a discussion of the need for a standard terminology and for the collection of compatible global data to enable progress to be made in correlational geology (the relationship of geological strata across regions or continents). The necessity of a more detailed understanding of correlational geology for economic and social progress is discussed. A list of the major topics where international cooperation is needed is given, with examples of each class of research. Problems of educating earth science specialists, particularly in the developing nations, are reviewed; the necessary supporting services for an International Geological Correlation Program (IGCP) are identified; suggested proposals for implementing and coordinating IGCP are listed; and the relation of IGCP to other international programs is outlined. Speeches by the Director-General of UNESCO and the President of the International Union of Geological Sciences, a list of the major correlation problems arranged by geological era, the proposed statutes governing the IGCP Board, and a list of conference participants are appended. (AL)

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Final report

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Intergovernmental Conference of Experts for Preparing an International Geological Correlation Programme (IGCP)

Paris
19-28 October 1971

Unesco

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I. INTRODUCTION

The idea of a long-term programme of international co-operation in major fields of geological sciences was introduced in 1964 into Unesco's general programme. In November 1966, the Unesco General Conference supported geological correlation as a key element of its earth science programme and the IUGS (International Union of Geological Sciences) observer recommended the execution of a broad specific programme as a co-operative Unesco/IUGS venture. In October 1967, the principles and statutes of the programme were elaborated by an IUGS/Unesco ad hoc committee in Prague and, in 1968, were approved by the IUGS Council in Prague. The scientific content of this programme and the ways and means of carrying it out were developed by a meeting of experts in Budapest in 1969 (UNESCO/SC/MD/16) which recommended the execution of an "International Geological Correlation Programme" (IGCP) as a joint Unesco/IUGS enterprise. In February 1971 a meeting of experts, representatives of international scientific unions and associations, and representatives of the Unesco Secretariat, was convened at Unesco Headquarters, to develop plans and make suggestions for the Intergovernmental Conference of Experts to be held in October 1971. The views and proposals made at this meeting of experts were endorsed by the IUGS Executive Committee (Haarlem, February 1971).

In February 1971, the Director-General of Unesco sent a circular letter (CL/2121) to the Member States requesting their views on the proposed IGCP. To this letter 40 countries replied and all of them showed interest and support for IGCP.

In accordance with resolution 2.321 adopted by the General Conference of Unesco at its sixteenth session, the "Intergovernmental Conference of Experts for Preparing an International Geological Correlation Programme" was held at Unesco Headquarters, Paris, from 19 to 28 October 1971. Working papers (UNESCO/SC/IGCP/6, 7, 8) had been prepared by the Secretariat for this Conference.

In his opening address, Mr. René Maheu, Director-General of Unesco, after welcoming the participants, recalled that the purpose of the meeting was to discuss major aims and objectives of IGCP, to prepare the final draft of the Programme, to specify the procedures of its execution and to prepare the Programme for adoption by the Council of the International Union of Geological Sciences and the General Conference of Unesco at its seventeenth session. (For full text of the speech of the Director-General see Annex I.)

The delegates were then addressed by Mr. K.C. Dunham, President of the International Union of Geological Sciences. After welcoming the participants, Mr. Dunham reviewed briefly the history and background of IGCP, mentioned the activities within IUGS in support of IGCP, the close co-operation of IUGS with Unesco to this end and expressed hope for a successful conference which would accrue to the benefit of IGCP. (For full text of the speech of the President of IUGS see Annex II.)

The Conference elected its Chairman, Mr. G. P. Salas of Mexico, nominated by France, with the support of Iran. The complete Bureau elected for the Conference consisted of:

President:	Mr. G. P. Salas (Mexico)
Vice-Presidents:	Mr. V. Ianovici (Romania) Mr. J. A. I. Olowu (Nigeria) Mr. F. Bozorgnia (Iran)
Rapporteur:	Mr. W. P. van Leckwijck (Belgium)

The Conference adopted its Rules of Procedure (SC/IGCP/6). In this connexion the delegate of Romania declared that his Government considers that the only legitimate representatives of the Chinese people is the Government of the Chinese People's Republic. Similarly the Romanian Government considers that the only legitimate representative of the People of South Viet-Nam is the provisional revolutionary Government of South Viet-Nam. The Romanian delegation also expressed the regrets that countries such as the German Democratic Republic, the People's Democratic Republic of Viet-Nam and the People's Democratic Republic of Korea had not been invited to take part in the Conference. The delegates of the Union of Soviet Socialist Republics and Czechoslovakia associated themselves with these views. The delegate of the Republic of China reaffirmed its sole right to participate in the Conference.

The following 52 Member States were represented by experts at the meeting.

Algeria
Argentina
Australia
Austria
Belgium
Brazil
Bulgaria
Burundi
Byelorussian SSR
Canada
Central African Republic
Chad
China
Czechoslovakia
Denmark
Dominican Republic
Federal Republic of Germany
Finland
France
Gabon
Guatemala
Honduras
Hungary
Iran
Iraq
Ireland
Israel
Italy
Japan
Liberia
Mexico
Monaco
Netherlands
New Zealand
Nigeria
Norway
Poland
Romania
Saudi Arabia
Spain
Sweden
Switzerland
Tanzania
Thailand
Ukrainian SSR
Union of Soviet Socialist Republics
United Kingdom
United States of America
Venezuela
Viet-Nam
Yugoslavia
Zambia

The Holy See was represented as an associate Member State.

Also represented at the meeting were the United Nations and its Economic Commission for Africa, the League of Arab States, the International Council of Scientific Unions (ICSU), the International Union of Geological Sciences (IUGS), the International Geographic Union (IGU), the International Union of Goedesy and Geophysics (IUGG), the Inter-Union Commission on Geodynamics (ICG), the Commission for the Geological Map of the World (CGMW), The International Association for Mathematical Geology (IAMG), the International Association of Hydrogeologists (IAH), the International Union for Quaternary Research (INQUA), the International Association of Engineering Geology (IAEG), the International Federation of Societies of Economic Geology (IFSEG), the International Society of Soil Science (ISSS), and the International Association of Volcanology and Chemistry of the Earth's Interiors (IAVCEI).

The full list of participants is given in Annex V.

After considering the Secretariat's proposals on the matter, the meeting adopted the following agenda:

1. Opening of the Conference by the Director-General of Unesco
2. Address by the President of the International Union for Geological Science (IUGS)
3. Election of the Chairman
4. Adoption of the Rules of Procedure
5. Adoption of the Agenda
6. Election of Vice-Chairmen and a Rapporteur
7. Report on the preparatory work
8. General content of the proposed programme
9. Constitution of the working groups and election of their Chairmen, Vice-Chairmen and Rapporteurs
10. Scientific content of an International Geological Correlation Programme
    (a) Chronostratigraphy and its practical implications
    (b) Geological events in time and space and their implications in environmental processes
    (c) Genesis of economic mineral deposits and the relations of metallogenic epochs to events in earth history

(d) Quantitative methods in geological correlation and data processing

11. Structure, co-ordination and execution of an IGCP

(a) Education and training of earth scientists and technicians as part of the programme
(b) Other supporting activities and basic operations required for the programme
(c) Mechanisms for co-ordination and execution of the programme

12. Adoption of the report and recommendations of the Conference

13. Closure of the Conference

II. GENERAL DISCUSSION

1. After hearing a statement by Mr. Batisse, of the Unesco Secretariat on the preparatory work undertaken for the Conference, a general discussion took place on the objectives and content of the proposed Programme, Item 8 of the agenda.

2. Twenty-six delegations contributed to this discussion. All delegations welcomed the programme and expressed their desire for its early implementation. Some delegations expressed what seemed to be a general feeling, that this Programme provides for the first time a framework for a fully international and interdisciplinary co-ordination of geological activities and research work carried out all over the world, by surveys, universities, academies and institutes of all kinds. Moreover, various delegations compared IGCP with similar international scientific programmes now in activity, such as the International Hydrological Decade (IHD), the Intergovernmental Oceanographic Commission (IOC), the Man and the Biosphere Programme (MAB), the Global Atmospheric Research Programme (GARP), the Geodynamics Project (ICG) or of less recent dates, the Upper Mantle Project and the International Geophysical Year, which are achieving or had achieved considerable success.

3. General support for the principles and objectives of IGCP were unanimously expressed, although some countries were hesitant about giving unqualified support to all proposals made for the programme content.

4. A great majority of delegations were in favour of setting up IGCP as a joint venture on equal terms between Unesco, as an intergovernmental United Nations organization and IUGS, as a non-governmental scientific union; i.e. a new type of venture of which a very recent example was given: GARP (Global Atmospheric Research Programme), a joint project between WMO (World Meteorological Organization) and ICSU (Scientific Committee on Oceanic Research) some of the countries added that, at the same time, the importance of preserving the integrity and functions of IUGS should be recognized.

A few delegations were of a somewhat different opinion and recommended that IGCP remain an IUGS concern with Unesco lending, through its Member States, full support to the existing correlation activities of IUGS. One delegation expressed specifically the view that partnership between Unesco and IUGS in IGCP should be at such a level that the selection of specific individual projects, their administration and the allocation of general IGCP funds to specific projects within each of the four major divisions of the Programme would remain with IUGS.

5. Some anxiety was shared by several delegations concerning the very wide scope of the Programme. The almost unlimited geological scope proposed for IGCP appeared to some almost a proposal to cover the entire field of geology and the whole activities of IUGS. Many countries would anticipate that the Programme will be limited to a number of clearly defined projects, each of which would be carried to a conclusion within a definite and reasonable period of time.

6. In relation with the foregoing point, it was considered by some delegations that the term "correlation" should be understood restrictively as meaning time-correlation of rocks and geological events, on a global, continental, or at least regional scale, in any or all fields of the geological sciences.

Many other delegations, however, were for taking correlation in the sense of correlation in time and in space. Still others consider that correlation should be interpreted in the broadest possible sense so as to give a fresh impetus to research in geology and other earth sciences.

7. Some concern was also expressed regarding what appeared to be a burdensome number of committees, boards and meetings and that much of the funds available for geological projects would be eaten up by overheads. It was hoped that the Programme would be run with a minimum of administrative and organizational expense.

8. Stress was laid on the necessity of avoiding duplication and conflict between the proposed IGCP Working Groups and the already existing IUGS Commission on Stratigraphy, its subcommissions and committees, and other IUGS commissions and committees, and between IGCP and IUGS associate bodies, such as INQUA, CGMW, IPU (International Palaeontological Union), IAS (International Association of Sedimentologists), IFSEG (International Federation of Societies of Economic Geology), ICG (Inter-Union Commission on Geodynamics), etc.

At the same time the hope was expressed that the IGCP would use the existing organs of IUGS as vehicles for carrying out IGCP projects.

9. Besides the study of the Phanerozoic, which forms a large part of the Programme, various delegations underlined the importance, as clearly outlined in the scope of the Programme, of the Precambrian, on account of the overwhelming proportion of time it covers in earth's history and the numerous and diversified mineral resources it contains, and of the Quaternary, on account of the present-day problems, such as of water, land use, environmental quality, for an expanding population and for the geological evidence it provides on changes of climate and sea level. Some delegations also stressed the importance of marine geology to IGCP.

10. Delegates of several countries emphasized the need for IGCP projects to have, whenever possible, a practical importance as well as scientific interest.

11. Developing countries pointed out that, for the benefit of these countries the Conference should lay stress on the practical aspects of correlation and its potential benefits for natural resources development. They also hope and trust that moral and financial support would be given to them through IGCP to promote local geological investigations within the framework of IGCP.

12. Lack of trained manpower and of experts in the developing countries was especially stressed. This led them to emphasize the urgent need for education and training in conjunction with IGCP.

13. Some countries expressed the view that the proposed membership of the IGCP Board should be increased, particularly to take account of the need for an equitable geographical distribution. While in agreement with this objective the Assistant Director-General of the Science Sector of Unesco and the President of IUGS warned against the building up of too large groups.

14. The delegate of Brazil considered that the Board should consist of Member States elected by the General Conference of Unesco and expressed its disagreement with the proposed procedure of selection of individual scientists.

15. The delegate of ICSU considered with favour the mobilization of international scientists toward the achievement of an important aim. ICSU had launched, with WMO, and GARP for just such a purpose, and was giving its full support to a joint venture between Unesco and IUGS for IGCP.

16. The Conference expressed its deep regret at the passing away of Professor A. A. Bogdanoff, President of the Sub-commission of the Tectonic Map of the World.

17. After the discussion of the general content of the Programme, the Conference established five working groups to consider items 10 and 11 of the agenda.

These five working groups elected their officers. Slight changes of titles were adopted by the first four working groups.

Working Group I	Time and Stratigraphy: The Practical Implications
Chairman:	Mr. C. W. Drooger (Netherlands)
Vice-Chairman:	Mr. V. Menner (USSR)
Rapporteur:	Mr. D. J. McLaren (Canada)
Working Group II	Major Geological Events in Time and Space and their Implications in Environmental Processes
Chairman:	Mr. G. Kautsky (Sweden)
Vice-Chairman:	Mr. H. H. Camacho (Argentina)
Rapporteur:	Mr. V. Bucha (Czechoslovakia)
Working Group III	Distribution of Mineral Deposits in Space and Time and Relation of the Processes of Ore Formation to other Events in Earth History
Chairman:	Mr. N. H. Fisher (Australia)
Vice-Chairman:	Mr. J. L. Saria (Tanzania)
Rapporteur:	Mr. P. W. Guild (U.S.A.)
Working Group IV	Quantitative Methods and Data Processing in Geological Correlation
Chairman:	Mr. S. C. Robinson (Canada)
Vice-Chairman:	Mr. H. Stigzelius (Finland)
Rapporteur:	Mr. G. B. La Monica (Italy)
Working Group V	Structure, Co-ordination and Execution of an IGCP
Chairman:	Mr. J. Marçais (France)
Vice-Chairman:	Mrs. C. Petzall (Venezuela)
Rapporteur:	Mr. H. K. Erben (Federal Republic of Germany)

III. MAJOR AIMS AND OBJECTIVES OF IGCP

A well-functioning International Geological Correlation Programme should aid in obtaining the answers to interrelated theoretical and practical geological problems, through international co-operation. Practical geological problems are constantly becoming more urgent.

The "population explosion" is resulting in a rising demand for consumer goods of all sorts and this is reflected in an increased demand for minerals. It also implies a rising demand for energy which involves fossil fuels, minerals for nuclear power, and geothermal power sources. As a result of this increasing demand for minerals and energy sources, it is evident that the world will face a critical shortage of some mineral resources within the next few decades. This shortage will become more acute as the standard continues to be raised.

Prospecting, based on improved geological knowledge and geological methods is essential for increasing adequately the known mineral resources. Geological correlation, taken in a broad sense, will provide an important means for locating new resources and spatially extending those which are already known. Likewise, rural and urban development must be planned with proper consideration of recent geological events and processes.

On the other hand, geological sciences must derive general principles from analysis and understanding of regional phenomena, which may have their clearest expression in widely distant parts of the globe. Research in these sciences bears, therefore, a distinct mark of place and time of origin and cannot be extrapolated as readily as the results of research in other physical and chemical sciences. For example, one of the most important concepts in geology is the relationship

between geological time and sequences of rock strata. This concept has usually been modelled on national traditional thinking. Furthermore, standards, terminology and classification differ from country to country. The geological sciences thus develop along different lines and, with the ever increasing amount of locally accumulated knowledge, these paths keep on diverging. Therefore, the solution of many, if not all, basic geological problems would be greatly facilitated and accelerated if data from adjoining areas, or even from distant continents, were made more intelligible to geologists all over the world.

In geological correlation, we are now taking advantage of the introduction of radiometric dating, of geophysical and geochemical methods, of new concepts in biostratigraphy, of automatic data processing methods, and of advanced mathematical techniques. It is therefore urgent to take the necessary steps before the present information explosion and the subsequent even more accelerated evolution of geological thinking continue to expand into too highly specialized regional or national geological languages, not readily understood by scientists of other countries and regions.

A solution to this problem has two aspects: one calls for standardization and implies universally accepted definitions (terminology), while the other needs actual research to establish clear documentation upon which accurate continental and intercontinental correlation will be based. It seems obvious that the solution can only be reached through a truly international programme to be carried out under highly qualified scientific authority and to be supported by general governmental agreement.

It is, of course, fully recognized that the established organs - affiliated associations, commissions and sub-commissions of the non-governmental international scientific unions dealing with the earth sciences - IUGS, IUGG, IGU, ISSS - and also the national governmental technical services and research institutions - geological surveys, universities, academies and industry - have been and are carrying out work which directly or indirectly relates to the problems described above, that is: standardization and establishment of clear documentation. The value of this work is great and irreplaceable. Nevertheless, it must be admitted that due to the principally national interests and obligations of governmental technical services, universities or industry, and to the frequently specialized nature of many international non-governmental scientific organizations, many areas of importance, especially where they require international interdisciplinary action, do not receive the attention they deserve.

The aim of the Programme, therefore, is not only to support and strengthen existing geological correlation activities but also to tackle and find answers to those problems which cannot be solved in the present framework of activities.

It is obvious that if a programme is to be truly international, it must contain elements which interest most nations. A programme consisting exclusively of advanced scientific studies and extensive collection of complex data might seem of lesser immediate interest to countries which are not highly developed from the scientific or economic standpoints, since in these countries immediate practical problems have a prior claim on funds and technical personnel. Conversely, a programme consisting largely of basic geological mapping and routine data collecting would not satisfy the interests or meet the needs of highly developed countries. None the less, the participation of many countries, large or small, advanced or developing, can be secured by means of a judicious compromise, by a combination of both types of activities referred to above.

The general principles of the proposed international correlation programme and the conditions in which it is to be carried out show clearly the wide range of problems and the need to deal with them on a long-term basis. Owing to the variability of geological environments, many geological factors cannot be correctly analysed unless observation data extending over five, or even ten years are available. The essential aim of the Programme could not therefore be achieved by means of a short-term programme. It is considered important for this reason to make provision for participating countries to undertake periodic and critical evaluation of projects, appraisal of progress achieved and consideration of future action to be taken.

For the same reason, the Programme, while firmly centred on international geological correlation, should maintain a flexibility both in content and approach. It should be foreseen that, as some activities become completed, others may change in direction and new projects can be added as and when the need arises.

IV. SCIENTIFIC CONTENT OF IGCP

The scientific problems to be solved in order to achieve the aims and objectives of IGCP affect many related fields of science. This is not only due to the great variety of research methods and techniques to be used but also to the great diversity of geological problems to be tackled. These range from those dealing with geochronology and stratigraphy, to studies of palaeontology, volcanism, metamorphism, tectonics, economic mineral deposits, and include data processing.

The geological time aspects strongly influence the methods and research techniques to be used in the execution of the individual projects. Because of the constantly progressing evolution of the earth's crust and surface, the problems presented to IGCP will differ considerably in their dependence on the geological age of the strata, of geological events, and of mineral deposits.

For practical purposes the geological column may be subdivided into the following three units, very different as to the geological time they represent but more nearly equal as to the work devoted to them by geologists and the natural resources contained in them.

The Precambrian, representing the first four thousand million years of the history of the earth, consists of rocks containing little evidence of life (the "Cryptozoic"). The Precambrian represents a great field of expansion of geological correlation particularly since the introduction of radiometric dating methods, before which possibilities of correlation within this enormous time span were very limited. However, most of the work, especially that of an intercontinental of world-wide scale still remains to be done. This is an enormous task since the Precambrian represents about 85% of the total length of geological time. Further, its rocks, either outcropping or covered by younger sediments, occur abundantly on all continents, so that large areas must be studied. In these rocks, the largest and richest deposits of some metals (e.g. gold, iron, uranium, nickel) and significant deposits of most minerals occur. Correlation is an important aid in the exploration for further mineral reserves.

The Phanerozoic (the Quaternary excluded) comprises some 570 million years of the history of the earth and is characterized by the explosive development of the organic world, which has provided excellent means for correlation by relative datings. The fossils preserved in the rocks of the Phanerozoic offer excellent opportunities to study the evolution of plants and animals. The pre-Quaternary Phanerozoic in general constitutes a field of consolidation and refinement of the correlation methods of all categories. This major portion of the Phanerozoic is today almost our exclusive source for fossil fuels and it contains many of the other most actively sought after mineral resources. Exploration for further resources requires refinement of biostratigraphical correlation in combination with basin and facies analysis as well as correlation of volcanic, metamorphic and tectonic phenomena. These more practical aspects of IGCP are closely linked with the scientific progress in stratigraphic correlation as well as to a better understanding of major geological events in time and space and their relation to environmental processes.

The Quaternary, comprising about the last two million years of the Phanerozoic, represents that phase of the development of the earth which includes the prehistorical and recent environment of Man. As in the major part of the Phanerozoic, the study of the Quaternary represents an opportunity for the refinement of correlation methods, particularly with an actualistic background for the understanding of facts and events to be correlated. Accurate correlations within this latest phase of earth history are a prerequisite for the use of geology as a predicting science with regard to the environment of Man. The Quaternary deposits are largely the immediate substratum for human land use and agriculture. They are the most immediate source for bulk material for construction of roads and buildings. In large parts of the world, they are the main, and most easily polluted source of ground water. Problems of the pollution of the environment and most of the physical natural catastrophes are connected with aspects of Quaternary geology. Sea level changes, for instance, would have disastrous results for large areas of low-lying densely populated countries. Better knowledge of Quaternary geology, such as more refined time concepts, correlation of deposits of glaciated and non-glaciated areas, the comparative study of types of weathering and their relation to the climatic conditions, genesis and correlation of both palaeosols and recent soils, research on sea level changes, will thus become an integral part of the scientific activities within IGCP.

For more details see Annex III.

The scientific areas of interest which will receive most attention of IGCP fall into four divisions. Each of these contains several topics.

Division 1	Topics
Time and Stratigraphy: The Practical Implications	Stratigraphic principles and the need for a common language The methods of stratigraphic correlation Standard definition of the major units of a global chronostratigraphic scale
Division 2	
Major Geological Events in Time and Space and their Implications in Environmental Processes	Patterns of erosional, sedimentary, climatic and biologic processes Patterns of igneous, tectonic and related metamorphic processes Patterns related to global and extra-terrestrial processes
Division 3	
Distribution of Mineral Deposits in Space and Time and Relation of the Processes of Ore Formation to Other Events in Earth History	Fuels and other economic mineral deposits in sedimentary rocks Economic mineral deposits related to igneous activity Economic mineral deposits related to tectonic processes Economic mineral deposits related to weathering
Division 4	
Quantitative Methods and Data Processing in Geological Correlation	Standardization and automatic data processing Geomathematical methods.

The scientific content of the four divisions was discussed in their respective working groups. Examples of problems given in the following text may be considered only as illustrations and there is no desire to indicate that these have priority or in any way are exclusive of other material that might have been used as examples.

DIVISION 1 - TIME AND STRATIGRAPHY: THE PRACTICAL IMPLICATIONS

The history of the earth, virtually from its origin to the present may be derived from the examination of the positional relationships of rock and mineral bodies. The superposition of sedimentary rocks is a special instance of this general rule and its study constitutes the main elements of the discipline of stratigraphy. This unifying principle of all geology allows time-scales to be constructed, absolute and relative, and these are progressively refined. Time correlation is the means by which events recorded in one area of the earth may be temporarily related to a regional or world-wide time-scale. Correlation may be achieved by many methods, or a combination of several, e.g. biochronology, radiometric age determination, palaeomagnetic phenomena, volcanic and tectonic events. These methods vary in effectiveness according to scale and the sector of geological time concerned.

While the methods of correlation already involve many disciplines within the earth sciences, their extension, refinement and mutual calibration is of major concern to geologists and can, in return, offer each discipline a tool of great practical importance. The demonstration of time equivalence between otherwise apparently unrelated events as well as correlation of related events are of fundamental importance and are basic to further exploration for an exploitation of fuels and other mineral resources on land and below the oceans, to land use and planning, and to hydrology. Stratigraphic classification and correlation are central to the multidisciplinary synthesis required to provide an intellectual base to all scientific and socio-political aspects of man's life on earth, and the relationship to his environment of land, sea and air. They allow man to study the development of the physico-chemical environment and the evolution of life from the beginning to the present and to predict future configurations resulting from natural development or from man's own activities. They concern man's place in nature, both physically and biologically and his increasing power, for good or ill, as a mjor modifier of the environment.

DIVISION 1, TOPIC 1 - STRATIGRAPHIC PRINCIPLES AND THE NEED FOR A COMMON LANGUAGE

In order to carry out the objectives of stratigraphy a common language is required to allow easy and rapid communication between scientists in different regions of the world and between specialists of different disciplines within geoscience. Although rigidity in definition should be avoided, there is need for a common understanding of concepts and of continuing efforts to come to broad agreement on the terminology of stratigraphic classification as well as the principles on which it is based.

The general areas in which definition of principles and a coherent common language are required include: (i) the principles of stratigraphy, including definition of the chronostratigraphic hierarchy e.g. the meaning of such terms as system, series, stage; the procedures to be followed in defining lithostratigraphic, biostratigraphic, and other stratigraphic units as well as the meaning and significance of such terms; the definition of stratotypes; (ii) the design of legends and conventional symbols for geological maps of all scales and an agreement on objectives in the preparation of such maps and the means by which this may be met. In this context the term map is taken to include all forms of cartographic representation including surficial and bedrock deposits, surface and subsurface geology, structure, metallogeny, palaeogeography, geochemistry, engineering geology, as well as vertical representation of stratigraphy and structure.

Example

Stratigraphic classification

The work of the Sub-Commission on Stratigraphic Classification of the Commission on Stratigraphy (IUGS) has been directed towards defining a common language in stratigraphy for some 20 years and should be encouraged and expanded.

Preliminary reports on principles, definition of systems, lithostratigraphic units, and stratotypes have been published and others on biostratigraphic and chronostratigraphic units are in press. These represent a first step towards defining a common language and concepts, and have engendered world-wide interest and debate. Such debate should continue.

It is suggested that the work of the International Sub-Commission on a Guide to Stratigraphic Terminology and Classification be used provisionally in IGCP projects as a basis on which further progress in this field can be built.

Particular difficulties are encountered in dealing with the vast period of time represented by the Precambrian and by the peculiar complexity of the most recent Phanerozoic system - the Quaternary. There is need for continued examination of the application of principles in regard to these important successions and for international effort in refining concepts and research into new techniques and methods.

DIVISION 1, TOPIC 2 - THE METHODS OF STRATIGRAPHIC CORRELATION

Many methods of correlation are in use. They may be of local, regional, or world-wide applicability, and vary according to geological age and rock type, e.g. the relative importance of individual methods varies widely between the Precambrian, the Phanerozoic and the Quaternary.

Remarkably little has yet been done to examine and establish the degree of accuracy and precision that it is now known can be achieved by methods of correlation, individually or relatively in comparison to one another. Although the improvement of methods will allow increasing refinement, the gradual nature of most of the underlying processes and of the limits inherent to our techniques, mean that the margin of error can never be reduced to zero. Better knowledge and understanding of such errors will be of value to all earth science, and may well influence principles, common language, and the chronostratigraphic scale.

Of major concern is the calibration of different methods in time correlation. Such calibration requires world-wide pilot studies of selected horizons at selected stratigraphic sections. The largest number of fossil groups, faunal and floral, should commonly be used to give a spectrum of

occurrence at a particular horizon allowing an accuracy of correlation far greater than that achieved by a single zone fossil or selected group.

Such definite horizons must be tested against and co-ordinated with studies on radiometric ages, palaeomagnetic changes, and a broad series of local and regional physical parameters including sedimentology and facies development, volcanicity and intrusion, tectonic and metamorphic events, geophysical and geochemical phenomena. Such interdisciplinary calibration must extend below the oceans in order to provide an accurate and flexible time-scale to chart the history of the ocean basins and their margins. It is from such oceanic margins that the next major wave of discovery of fuels and minerals may be expected, and the study of their history is one of the most challenging areas in geology today. Calibration of stratigraphic methods is essential to all geoscience, and considerable support is needed for a wide variety of interdisciplinary pilot studies.

Examples

Evaluation of methods

Multidisciplinary research is needed on a considerable number of selected reference sections in order to compare various dating methods. In addition to research on as many faunal and floral groups as possible including the use of biometrics and statistics, radiometric and paleomagnetic dating is required together with a thorough background knowledge of regional stratigraphic, sedimentological, tectonic and geochemical data. Research should be carried out by several international groups of specialists on sections from different parts of the time-scale. Wherever possible they should consider the inter-correlation of marine and continental deposits as well. As an illustration of such multidisciplinary research, observations made during the field meetings of the Committee on the Silurian-Devonian boundary showed that the combination of results from several fossil groups provided far greater accuracy of correlation than could have been achieved using any single faunal zone or fossil group.

Biochronology is of less relevance in the Precambian and presents special problems in the Quaternary; other methods need to be developed and refined. Radiometric age determination is highly important to both intervals. The analysis of cyclical world-wide events and of directional physical and biochemical processes hold out hope of further refinement of the Precambrian time scale. The duration of the Quaternary system is too short for evolutionary biochronology to be fully effective, but changes through time of environmentally controlled faunas and floras may be used effectively for local and regional correlation. Such methods, combined with climatological analysis, require major international efforts to develop and refine.

DIVISION 1, TOPIC 3 - STANDARD DEFINITION OF THE MAJOR UNITS OF A GLOBAL CHRONOSTRATIGRAPHIC SCALE

Having examined the principles of stratigraphy and the methods of correlation, it is important to stress the need for definition of units in a time-scale established by stratigraphic methods. Age equivalence of rocks and their contained fossils, which vary in their character from place to place, may be established by a variety of correlative techniques; but the framework for geological history requires precise definition of the units used to subdivide time. Names established in the past for major units by the International Geological Congress or by general usage include those for systems, series and stages, and should be preserved as far as possible. Unfortunately at present the precision with which most units of the geological column have been defined falls far short of the accuracy that may be achieved in attempting to correlate such units on a regional or world-wide basis. Remedy for this lack of definition is a matter of urgency and is essential for the exploration for gas and oil throughout the world.

A chronostratigraphic unit is defined by reference to a rock sequence considered to characterize a certain time interval at a specific locality which should be so chosen as to maximize the possibility of world-wide correlation. Such defined sequences are known as stratotypes; they may contain a boundary (boundary stratotype) between two defined sequences. Many chronostratigraphic units have been established in a somewhat haphazard manner in the past and their boundaries are such that accurate correlation is precluded. While preserving priority of nomenclature as far as possible, it is necessary to redefine many such units at more carefully chosen type sections following study and research on a world-wide basis.

Examples

It is difficult under this topic to give specific examples in that, with few exceptions there are no satisfactorily defined boundaries in the geological time-scale. For over ten years a Committee of the Commission on Stratigraphy has been engaged in reaching a satisfactory definition for the Silurian-Devonian boundary. Agreement has now been reached by the Committee and a recommendation will be made to the Commission at the 24th International Geological Congress. Boundary definitions have been of particular concern in the study of the Phanerozoic rocks. The situation for the Precambrian is more difficult. For, in this age-unit, representing a large percentage of all geological time, there are as yet no universally accepted criteria on which to base definition of chronostratigraphic units, although it is clear that such criteria must exist. In the youngest part of the column, the Quaternary System, difficulties are further magnified by the unique variability in succession from place to place, by the shortness of the time interval involved, and by the complexity of events that have shaped the deposits of the system. Definition thus becomes a matter of utmost importance at all levels in the time-scale if the full potential of the stratigraphic method is to be realized. The Commission on Stratigraphy of the IUGS is charged with the responsibility of defining chronostratigraphic units on a world-wide basis. Without international agreement such definition cannot be achieved, and the Commission should be the central co-ordinating body of all projects under the IGCP that are concerned with definition of the geological time-scale. Perhaps no other single topic requires such a concerted world-wide effort, and this must be considered as a fundamental need upon which the success of the IGCP must ultimately depend.

DIVISION 2 - MAJOR GEOLOGICAL EVENTS IN TIME AND SPACE AND THEIR IMPLICATIONS IN ENVIRONMENTAL PROCESSES

An outstanding need in all geological work is to identify patterns in time and space and any correlations that may exist between different kinds of phenomena - planetary, magnetic, tectonic, plutonic, volcanic, metamorphic, climatic, eustatic, sedimentary and biological. These phenomena include the fundamental processes that shape man's environment, and an understanding of their relationships with one another will benefit mankind not only in terms of total scientific knowledge but also in terms of mineral wealth. The proposed methods of correlation include relating quite different phenomena to one another as well as relating events in time.

By means of geophysical and palaeogeologic maps, successive positions of crustal plates may be used in any selected palaeogeologic reconstruction. A time-sequence of alternative base-maps could be used in successively eliminating later movements. Computer plotting of stratigraphic and other parameters, and the resulting fit, would help to decide between alternative craton mosaics for each time interval.

Although individuals and institutions have pursued similar objectives, the IGCP will generate a massive contribution in international co-ordination and integration of effort that will make it possible to study patterns of critical phenomena on a global scale and to discover new relationships. Such a co-operative programme is necessary to match the current explosion of information, information which in the earth sciences is accumulating so rapidly as to be collected only with difficulty by even the largest national institutions.

DIVISION 2, TOPIC 1 - PATTERNS OF EROSIONAL, SEDIMENTARY, CLIMATIC AND BIOLOGIC PROCESSES

Because significant changes have been and are continually taking place in the surface of the earth's crust, in its hydrosphere and atmosphere, and in the development of organic life, underlying patterns should be looked for and studied.

Investigations of facies patterns and sequences of sedimentary basins in platform, geosynclinal and oceanic environments should result in a greater knowledge of tectonic and palaeogeographic controls of mineral and chemical distributions. Major studies of stratigraphy, palaeontology, sedimentology, mineralogy and geochemistry, and the integration of these, should lead to interpretations of the evolution of environments, of their time correlations, and of distinctive beds resulting from changes in climate, salinity, sea level, and in tectonic and volcanic environments. Many minerals and rocks of great economic importance are found in particular sedimentary deposits, and the study of the pattern of their distribution will be of special value.

Evolution of life is familiar from the fossil record, and the interplay between faunal and floral development and physical environment is a major field for investigation. The limits of fossil ranges and rates of evolution are determined by factors not yet fully understood. The structure and chemistry of sediments are in turn affected by the biosphere, with the result that mineral concentrations may be produced.

Clarification of the interactions between tectonic, climatic, eustatic and biologic events will yield a better correlation of past facies, and the possibility of predicting future changes in climate and sea level.

Examples of general problems

Cyclical deposition of sediments

The study of associated rock types in sedimentary rhythmic units is of the greatest importance, as in the exploitation of coalfields that are laterally variable in rock sequence and are deformed by faulting and folding.

Patterns and changes in climate and sea level

Some pattern may underlie the periods of refrigeration that have affected the earth either at major intervals measured in many millions of years, or at shorter intervals measured in thousands of years as in the Quaternary. More intensive and world-wide search should be made for the causes of the climatic and sea-level changes which are so important for mankind.

DIVISION 2, TOPIC 2 - PATTERNS OF IGNEOUS, TECTONIC AND RELATED METAMORPHIC PROCESSES

Deep processes in the earth's crust and upper mantle are the cause of earth movements and rock deformation, the formation of magma which crystallizes at depth as plutonic rocks or erupts as volcanic rocks, and the metamorphism of former igneous and sedimentary rocks. The problem is twofold: (1) to identify patterns that establish the relations between different events which have occurred in an individual orogenic belt and (2) to correlate individual events which have occurred in different orogenic belts. Studies of this problem will generally require international co-operation.

Many studies have already been made in all parts of the world of tectonism, plutonism, volcanism, and metamorphism, and the time is ripe to bring these studies together and try to correlate systematic patterns. Local geometries and histories can be compared regionally, to identify and correlate global patterns and processes. It may be possible to adapt model experiments of an advanced type to clarify many features encountered within orogenic belts. Experimental work in the fields of geophysics, tectonics, geochemistry and petrology will result in a much improved understanding of deep earth processes.

Plutonism, volcanism and most of the other processes mentioned above are, in certain conditions, productive of useful minerals; the knowledge of the regularities governing the origin and distribution of mineral deposits will be substantially improved by correlation studies. This will result in a more efficient and successful search for mineral raw materials.

Examples of general problems

Correlation of geological events in older terrains incorporated in younger mobile belts

For example, the correlation of the Precambrian sequences of European Caledonian, Variscan and Alpine belts, can be achieved only by using litho-facies; volcanic, plutonic and metamorphic events; structural and geochemical patterns; and comparison with adjacent uninvolved cratonic sequences. The research necessarily involves also those important post-Precambrian events which substantially changed the patterns of the respective Precambrian complexes, are related to definite Precambrian structures and are productive in useful minerals deposited in Precambrian complexes.

Circum-Pacific Mesozoic and Caenozoic tectonism, plutonism, volcanism and metamorphism

The circum-Pacific mobile belt is well suited to an integrated study of tectonism because of its great extent, continuity, and long and varied geological history as the site of disappearing oceanic crust. Studies should consider the timing and relationship of deformation, metamorphism, generation of magmas and ore deposits, to underthrusting by the oceanic crust, mantle and deep ocean sediments. Extremely important to the survival and well-being of circum-Pacific peoples are studies of late Caenozoic volcanism, including correlations between petrochemical variation, age magnetic polarity and neotectonic deformation, with regard to the assessment of geologic hazards.

Characters of granitoid rocks and their relation to mineralization

Studies belonging to this subject concern the granitoid rocks of the globe, their chemical and mineralogical composition, their origin and their relations with many types of mineralization. Granitoid rocks are widespread in the mobile belts and cratonic blocks, and knowledge of their characteristics is indispensable for the understanding of the rest of the terrain. Studies carried out on geochemistry and radiometric dating will contribute to correlation between the chemical elements of the granitoids, and between chemical composition, age and ore mineralization.

DIVISION 2, TOPIC 3 - PATTERNS RELATED TO GLOBAL AND EXTRATERRESTRIAL PROCESSES

Numerous lines of evidence indicate that the earth's crust has undergone changes of global and continental extent which are recorded in the stratigraphic record. The evidence from studies of the movement of crustal plates and ocean floor spreading, of changes in tides, of meteoritic impact, of the length of the terrestrial year need to be collated. Considerable research is being fostered and co-ordinated by the scientific unions (particularly IUGG) and inter-union commissions such as the Geodynamics Project, and by intergovernmental bodies such as the Oceanographic Commission, but much remains to be done to synthesize the results and make them useful in stratigraphy and geologic time correlation.

The large-scale processes comprising this topic require for their elucidation further research in many fields, e.g. earth magnetism and palaeomagnetism, seismicity, heat flow and convection, tides, geodesy, geochemistry, palaeoecology and many others. The processes and the resulting effects involve such dissimilar questions as rates of evolution and the conditions for lunar capture. We anticipate that many kinds of information and new research will contribute to improvements in geologic correlation and the IGCP presents an unprecedented opportunity to promote interdisciplinary advances on a major goal of the earth sciences.

Example of general problems

Major forces in the earth's crust

The force (or forces) which move crustal plates and ocean floors, both vertically and horizontally, are unknown, although the geologic record seems to show clearly various kinds of plate movement. Existing ideas and new approaches must be correlated within the larger framework of geologic history and followed up by extensive research to identify the fundamental causes. Correlation between margins of continental masses which are now separated, notably Africa and South America, Antarctica and Australia, Australia and India, etc. is needed. For these studies comparison of magnetic, seismic, tectonic and sedimentary phenomena are especially useful. Such correlations may well clarify relationships necessary for identifying resources of economic importance.

DIVISION 3 - DISTRIBUTION OF MINERAL DEPOSITS IN SPACE AND TIME AND RELATION OF THE PROCESSES OF ORE FORMATION TO OTHER EVENTS IN EARTH HISTORY

Minerals and mineral fuels are key raw materials of the industrial age. The fuels provide heat and energy; metals and non-metals the materials for, among other things, our machines, buildings, transportation networks and communication systems. Most chemicals are based on

mineral raw materials; the fertilizers that enable agriculture to keep pace with expanding population derive largely from minerals. Virtually none of the enormous increase in the level of living in the industrialized nations would have been possible without the use of vast quantities of minerals, and still greater amounts will be needed in the future for the developing countries.

The mineral raw materials are non-renewable. Reserves of some are already seriously depleted and the requirement to provide at the same time for the continuing needs of developed countries and the expanding needs of the developing countries will tax the world's ability to supply them. The rapidly expanding population makes the problems even more serious.

It is true that lower grade ores can now be mined and processed and that improved geophysical and geochemical techniques have increased our ability to find new deposits. But the lower limit of economically exploitable ores is being approached for some metals (for example material containing as little as a quarter per cent of copper is now being mined), and many of the more obvious anomalies found by geophysics and geochemistry have been tested. The time is fast approaching, if it is not already here, when ore deposits exposed on the surface or easily found by routine methods will no longer be available, and future discoveries must be based on precise understanding of the geological factors that determine the concentration of elements and minerals into localized ore deposits.

To achieve this understanding will require consideration of the entire body of geological knowledge about our planet, particularly: (1) correlation of data developed by all physical sciences, for each can contribute to deciphering the details of ore genesis; (2) geographical correlation, to identify significant ore-controlling features in areas where they are well developed or exposed and use them to guide exploration elsewhere; and (3) correlation in time, both absolute and relative, to determine the sequence of events that led to formation of mineral deposits. Because deposits of the types discussed below occur on every continent, international co-operation is indispensable.

DIVISION 3, TOPIC 1 - FUELS AND OTHER ECONOMIC MINERAL DEPOSITS IN SEDIMENTARY ROCKS

A large part of the useful minerals of the world occurs in sedimentary rocks. These include: the mineral fuelds, petroleum, oil shale, and coal; many important non-metallic minerals, common salt, potassium and magnesium salts, gypsum, limestone, dolomite, sand and gravel, and many if not most of the commercial deposits of phosphate rocks, sulphur, clay, fluorite and barite; and many deposits of metallic minerals such as uranium, iron, manganese, copper and lead-zinc silver. Some of these deposits were formed at the same time as the enclosing rocks, and their distribution was influenced by climatic, geographic, and other conditions affecting the chemistry of the local environment; an understanding of the occurrence of known deposits in relation to such features in both space and time over the world may establish a better scientific basis for prospecting for new deposits as it already has for certain kinds of marine phosphorites. Other mineral deposits in sedimentary rocks were emplaced after deposition of the host rock, either from source materials originally disseminated within the sediments themselves or brought in by migrating fluids. The localization of these deposits was also in large part controlled by sedimentary features (e.g. reefs, channels, breccias, lithofacies changes) many of which were also controlled by the geography and the climate prevailing at the time. Analysis of the patterns of distribution of economic deposits in sedimentary rocks as related to other events and phenomena, utilizing all available methods of palaeogeographic reconstruction, thus may be expected to yield effective guides that will aid in the discovery of new deposits.

Examples of general problems

Correlation of data on the occurrence of petroleum

Distribution of oil fields indicates that a connexion exists between oil formation and climatic conditions and that most oil accumulations were formed in comparatively low latitudes. In view of the general acceptance of continental movement and development of the means of precise palaeogeographic reconstruction, it is desirable to establish the latitudes of the various oil fields at the time of deposition of the sediments in which they occur. Such reconstruction could give direction to future prospection.

Another development relevant to the search for petroleum is the evidence obtained from some recent studies that organic matter of vegetable origin is a more important source of petroleum than has generally been accepted. If this is confirmed by further geological and chemical studies of suitable oil fields, more attention would be directed to the search for petroleum in non-marine sediments.

Correlation of the occurrence of phosphorites, salines and other minerals with palaeogeographic and palaeoclimatic phenomena

Geography and climate are two of the main controls in the localization of marine phosphorites, potash, rock salt and other saline minerals. The occurrence of similar conditions over large areas during certain geological periods has resulted in widespread distribution of such deposits. Analysis of these patterns of distribution in time and in relation to palaeogeographic, palaeohydrographic and palaeoclimatic history should help to define targets favourable for exploration.

Correlation of factors relating to the localization of stratabound base metal deposits

A world-wide comparison of specific environmental conditions relating to the localization of stratabound sulphide deposits of base metals (Cu, Pb, Zn) and of fluorite and barite, is of critical importance to meet future needs. Palaeogeographic and palaeoclimatic conditions; relationship to salt brines, the salinity of pore solutions, dolomitization, position relative to unconformities and volcanic activity, and the part, if any, played by living organisms, all need to be analysed.

DIVISION 3, TOPIC 2 - ECONOMIC MINERAL DEPOSITS RELATED TO IGNEOUS ACTIVITY

Important deposits of many metallic and non-metallic minerals are products of igneous activity, including the complete or partial melting of rocks and the mobilization of fluids under high temperature and pressure. Many such deposits are genetically related to intrusive and extrusive igneous rocks of various compositions. Many are also spatially related to igneous bodies such as batholiths, stocks, sills and dykes and, regionally at least, some may be correlated in time to igneous events. A comparative study of igneous-related deposits on a world-wide scale - taking into account geochemical, petrogenic, structural, spatial and time relationships - may be expected to yield patterns and correlations that will increase the effectiveness of exploration and lower its cost, particularly as applied to concealed deposits and to the search for deposits at increasing depths.

Examples of general problems

Correlation of occurrence of ore minerals associated with acid igneous rocks

Many mineral deposits are associated chiefly with acid igneous rocks. These include deposits of Sn, Mo, Ta, Nb, Th, Zr, Be, W, Cu, Au, Pb and Zn. A study of the deposits of these metals associated with acid igneous rocks throughout the world may establish the common factors in space and time, physico-chemical properties, paragenetic sequences, tectonic and geologic settings, and the trace element and isotopic variations. There are many specific problems that need to be examined. Why, for instance, are the vast majority of the tin deposits of the world associated with igneous rocks of Mesozoic, Tertiary and Upper Palaeozoic age, and so many of them with Jurassic quartzose granites? Why was tin deposition in the vast span of Precambrian time comparatively negligible? A study of the mineralogy and geochemistry of the tin deposits (most of which occur in developing countries) and the associated igneous rocks, would contribute to the understanding of these puzzling phenomena and to the search for new deposits.

Mineral deposits associated with basic and ultrabasic rocks

A wide variety of metals including Ni, Co, Cr, Ti, Pt, Cu and Zn, and also asbestos, are related to and spatially associated with basic and ultrabasic igneous rocks. Deposits of some of these appear to be correlatable with particular rock types, and further study of these associations should reveal additional patterns useful in the search for new deposits. For example, preliminary study suggests that nickel sulfide ores are more abundant and of higher grade in the earlier Precambrian rocks. If detailed correlation of petrology, grade and geologic age for all known deposits bears this out, a useful guide to selection of areas for exploration would result. Many of the potential regions lie in developing countries.

DIVISION 3, TOPIC 3 - ECONOMIC MINERAL DEPOSITS RELATED TO TECTONIC PROCESSES

Many mineral deposits are related to regional tectonic processes such as geosynclinal development, orogenesis, epeirogenic movements, ocean-floor spreading and continental drift. Because many major tectonic events are of continental or even intercontinental scale, the correlation of mineral deposits associated with them assumes great importance in providing clues to the location of both favourable areas and favourable stratigraphic levels for the occurrence of a wide variety of metals and minerals.

Examples of general problems

Correlation of mineral deposits formed during the development of Early Palaeozoic (Caledonian) mobile belts

The development of geosynclinal-orogenic belts of several ages in many parts of the world is accompanied at various stages by the formation of important deposits of both metallic and non-metallic minerals. A world-wide study of the patterns and sequences of sedimentary and igneous (especially volcanic) rocks formed during geosynclinal development to correlate them with metallogenic epochs would contribute greatly to solution of the problems of ore search in these mobile belts. The Early Palaeozoic, Caledonide-type belts seem to be especially well suited for a project that would on the one hand involve broad interdisciplinary co-ordination and on the other participation by many nations because of their widespread occurrence.

Mineral deposits related to fracturing of continental platforms

Important ore deposits occur in old platforms, especially the Precambrian ones. Many of these are related spatially and genetically to fracturing (reactivation) of the crust and introduction of materials from deep levels. For example, diamond pipes, carbonatites with columbium, tantalum, and phosphate minerals, and some veins of lead-zinc-fluorite are found in this environment.

Geologically young rift zones are areas of high heat flow that constitute potential sources of geothermal energy and in some areas are known to contain metalliferous deposits.

Because many of the fractures extend for very long distances but are difficult to trace continuously, remote sensing from satellites promises to increase greatly our ability to recognize these features. Correlation of ground- and satellite-based data could rapidly and relatively inexpensively provide new guides to exploration. This is particularly interesting to many developing countries in Africa, South America, and Asia which have extensive areas of Precambrian platforms within their national territories.

Correlation of mineral deposits on segments of continental blocks separated by continental drift

In the course of gathering evidence to demonstrate the reality of ocean-floor spreading, much attention has been paid to matching geologic features on opposing segments of continental blocks. As a result, it is now realized that knowledge of the distribution of minerals (including petroleum) on one side can be used to define favourable exploration targets on the other. As the capability for sub-sea exploration develops, interest will focus not only on minerals near the edges of continents and on the continental shelves but also on those that may exist in foundered segments of drifted continents.

DIVISION 3, TOPIC 4 - ECONOMIC MINERAL DEPOSITS RELATED TO WEATHERING

The most important deposits of many minerals were formed by weathering, either by removal of enclosing rock material to concentrate insoluble ore minerals or by downward chemical concentration of the valuable elements into residual blankets. Thus most of the world's placer deposits of gold, tin, monazite and other resistates have formed in areas of deep weathering. Bauxites (aluminium ore) and other laterites - including those rich in iron, nickel and cobalt, manganese, and phosphates - are examples of residual deposits formed in tropical climates. Bentonites are formed by surface alteration of volcanic ash. Kaolin is commonly residual. And karst development,

although not of itself a process of much importance in the enrichment or alteration of ore minerals, in many places provides the traps in which valuable deposits may be formed later.

Examples of general problems

Correlation of the factors controlling the laterization process in space and time

Analysis of the climatic factors, palaeolatitudes, topography, source rocks and other features affecting the formation of various kinds of laterites would aid in identifying areas favourable for the occurrence of economic deposits. For instance, although laterites are extremely widespread, minable bauxite is produced only under certain restricted climatic, topographic, geologic and chemical conditions which are still poorly understood. Both the physical parameters and the chemistry of the lateritization process need intensive study and correlation over many deposits throughout the world in order to formulate better criteria for further search for bauxite.

Similarly, a large part of the nickel and cobalt resources of the world are contained in laterite profiles developed over ultrabasic rocks in tropical and sub-tropical areas. Co-operative studies of the known widely scattered occurrences should yield information useful in guiding further exploration for this type of deposit.

Correlation of karst features in relation to mineral deposits

The process of karst formation has received more and more attention in recent years as a mechanism for the formation of deposits of economically important minerals such as bauxite, phosphorite, lead and zinc sulphides, fluorite and barite. Deposits formed by karstic processes occur in carbonate rocks beneath surfaces of unconformity, and recent discoveries of such deposits beneath ancient unconformities suggest that the processes may have been more common than has hitherto been suspected. A thorough study of present and fossil karstic formations on a world-wide scale should prove to be very fruitful from an ore-search point of view.

DIVISION 4 - QUANTITATIVE METHODS AND DATA PROCESSING IN GEOLOGICAL CORRELATION

Recent developments in data processing and mathematical procedures have greatly facilitated the assimilation and interpretation of data in geology and related sciences.

These procedures are essential for correlating and integrating great volumes of numerical data produced in geophysics and geochemistry with results of geological investigations, thus leading to more effective solutions of important problems. This is of special significance in the application of modern mineral exploration techniques in identifying areas of high potential for the occurence of different types of mineral deposits, and also in the handling of geological problems related to the environment.

The use of data processing in systematic ordering, comparison, interrelation and graphic presentation of data significantly reduces the time required and cost involved. The development of effective methods of storage and retrieval on the international scale would be of great assistance in the testing of major geological concepts and result in a more efficient investigation and development of natural resources.

It is recommended that IGCP should provide assistance in the fields of statistics and data processing for IGCP projects in developing countries.

DIVISION 4, TOPIC 1 - STANDARDIZATION AND AUTOMATIC DATA PROCESSING

Fundamental geoscience observations assembled in any specific project are of lasting value and must be expected to be of use in a broad range of geological research and exploration. For this reason, geological data from IGCP and other projects should, where possible, be recorded in computer-based data banks to make basic information readily available. It is strongly recommended that all data files should include factual field and laboratory observations, rather than merely conclusions.

The evaluation, international exchange and use of different national data banks and files implies that standardization of systems for the recording of observations is essential i.e. methods of standardization should be developed for each type of geoscience data (petrology, stratigraphy, sedimentology etc.). In this regard attention should be drawn to the advantages of semantic coding.

Standardization is likewise necessary for geographical data, because any geological observation and measurement is fixed in space. The systems used should allow one to convert the data by simple automated programmes to geographical co-ordinates (latitude, longitude, altitude) with narrative or coded specifications for political units (e.g. Netherlands) or natural units (e.g. Alps, Caribbean Sea). For coded specifications, existing systems like Geocode or BRGM-code should be used.

It is essential to apply the adopted standardization at the time of acquisition of any type of geoscience observation or measurement either in the field or in the laboratory, using rules which can be easily adopted by all participating scientists.

This complex of problems as a whole is now under the guidance of the IUGS-Cogeodata and its affiliated organizations, whose advice should be used for the IGCP projects. For IGCP projects it would be advantageous that the IUGS Committee on Geological Documentation and its Automation Board give routine help in all problems of indexing, storing and retrieving geoscience documents arising from IGCP projects.

Consideration should be given to the establishment of a means to facilitate the international exchange of computer programmes among geoscientists. This facility should establish an index of programmes and their specific functions, and should define their input and machine requirements.

DIVISION 4, TOPIC 2 - GEOMATHEMATICAL METHODS

In recent years there has been an increasing effort by geologists to analyse and interpret many types of geological information in quantitative terms. This leads to the more precise application of correlative and other data-based studies in geology and will allow for a more quantitative base in many aspects of the geological sciences.

A broad range of statistical and other mathematical methods used in geology are now practical with the availability of modern computers. With computers and appropriate methods of geomathematics, it is possible to reduce large amounts of geological data into manageable forms.

Geomathematics encompasses all of the areas of geology wherein the principles of mathematics are applied to the acquisition and analysis of geological data, but many of the techniques that are known to have broad application may be classified into three categories: (1) basic methods for the reduction and summary of large data volumes, (2) multivariate methods for the study of complex geological systems, and (3) time-series methods for the examination of geological events with cyclic properties.

In many practical problems in geology the types of data and the objectives are more or less unique and special basic methods are required. Examples where such methods have been applied to special problems occur in geochemical and geophysical exploration, ore evaluation, geological mapping, sedimentology, stratigraphy, and engineering geology. Basic methods suitable for the special problems encountered are already in current use, and more will appear as geologists continue the trend toward quantification.

Most geological phenomena have resulted from a complex system of processes and multivariate methods offer the best possibility of understanding such complex systems. These methods prove useful not only where numerical data are available, but also where conventional geological observations can be quantified. Some special multivariate methods which involve modelling of geological systems offer a great deal of encouragement in our attempts to understand the earth's history and to utilize this knowledge in practical economic and environmental problems.

Certain geological events, particularly those which bear on problems of correlation occur with some element of periodicity. The records available in the search for such periodicity, however, are commonly short, and analysis of the records must be especially rigorous. In recent years geologists have explored a broad range of time-series methods which have proved useful in geophysics

and other fields of science. Time-series methods will find increasing application to many problems in geology.

Geomathematical methods will continue to become increasingly important in all geological sciences, and will be especially needed in the effective utilization of earth science data banks now being assembled in many countries.

Recommendation for data processing secretariat activities

Because it is important that the procedures used in IGCP projects be compatible so that results may be compared, the Conference recommended that the Secretariat of IGCP gives proper attention and priority to this matter. It is further suggested that the Secretariat activities in this area be mainly organized through the IUGS Committee on geological documentation, the IUGS Cogeodata, the International Associations for Mathematical Geology, and the competent international organizations concerned. The secretariat should also provide lines with IGCP National Committees.

The secretariat would in this way act as a clearing house for information on data processing procedures and mathematical methods; it would advise project leaders on procedures; and should be responsible that the numerical data, observations and information accumulated in IGCP projects are recorded in terms that are compatible and comparable. As approved by IGCP the Secretariat would assist or arrange data processing assistance for IGCP projects in developing countries, and in association with IAMG prepare a bibliographic report of mathematical methods relevant to geology.

V. RÔLE OF EDUCATION AND TRAINING IN THE IGCP

The Conference felt that the modern developments in the earth sciences called serious re-examination of the content and methods of education in this broad field. It recognized that a proper orientation and development of education and training could facilitate the long-term goals of IGCP and that Unesco in particular should give full attention to its activities, either under the Regular programme, under UNDP or in conjunction with bilateral assistance projects. The Conference, however, considered that general education and training of earth scientists and technicians do not constitute a major objective of IGCP.

The Conference recognized that in many developing countries the specialists required for implementation of IGCP projects were not available or were not in sufficient numbers. It was noted that, taking the world as a whole there was probably no absolute dearth of geologists, but that their repartition among the different countries was far from adequate. It was also felt that in some more specialized disciplines, specialists were scarce everywhere. Under these circumstances, the creation or strengthening of training facilities in geology and other earth sciences was still required in certain developing countries, while keeping in mind the need for giving them adequate field training and the fact that only small numbers of specialists were required. Such facilities should include not only the training itself, but also the libraries, laboratories, collecting of specimens and field equipment required. In any case, however, the establishment of such training facilities in the developing countries is a long-term enterprise and shorter-term practical steps have to be taken to ensure the success of IGCP projects in these countries.

The Conference therefore devoted most of its time to the discussion of the education and training requirements directly linked to the implementation of IGCP. In this respect it recommended:

(a) that fellowships be granted for post-graduate specialized studies in other countries;

(b) that practical seminars and field courses of sufficient duration be organized in the developing countries on a regional basis to acquaint earth scientists from these countries with new methods and recent progress in various disciplines;

(c) that the implementation of IGCP projects be used in each country, particularly in the developing countries, for on-the-job training of specialists.

The Conference recommended that Member States intensify their efforts at the national level to these effects, and that developing Member States duly consider the possibilities offered by the UNDP for national or regional training programmes.

In relation to seminars and training courses, the Conference considered that the duration of such activities was in general too short, and that field work under real conditions was not given sufficient emphasis. It was stressed that IGCP would greatly benefit from such practical seminars relating to geological and geomorphological mapping and to general mineral surveying. It was also underlined that such regional training activities might best be organized among the countries having similar geological features.

The advantages of on-the-job training directly associated with implementation of IGCP projects were stressed. The Conference recommended that "partnership" arrangements be made between developed and developing countries on such projects so as to offer training opportunities for young specialists from developing countries.

The Conference brought out also the need to harmonize bilateral and multilateral assistance in relation to training activities, and to take into account the great diversity of situations and needs in the developing countries.

VI. BASIC OPERATIONS AND OTHER SUPPORTING ACTIVITIES FOR THE IGCP

A successful execution of the programme will require certain basic operations and other supporting activities to be carried out both on national and international levels.

The Conference was aware of the current activities and programmes conducted or sponsored by Unesco in the field of earth sciences and other environmental sciences. It recommended that in future years the Unesco earth sciences programme be oriented as far as possible towards those activities which will support IGCP directly or indirectly. It further recommended that developed countries consider the ways and means through which they can best assist developing countries to take full part in the implementation of IGCP projects.

The Conference considered that the following operations and supporting activities, besides education and training, should receive proper attention:

(a) The improvement of earth science cartography, including geological maps, tectonic maps, metallogenic maps, quaternary and geomorphological maps, hydrogeological maps, geotechnical maps, etc. In some areas, large-scale cartography is necessary both for scientific and for practical reasons. On a world-wide basis, small-scale maps, such as those which are prepared and published under the joint auspices of Unesco and of the Commission for the Geological Map of the World, are indispensable to present the synthesis of knowledge and to show correlations in space and time in the earth sciences for a better utilization of the land and underground resources. The preparation of such maps involved field discussions and symposia and the elaboration of legends for the maps constitutes fruitful space and time correlations of geological phenomena.

(b) The organization of field symposia and excursions related to IGCP projects. Such meetings will be necessary to study jointly relevant geological features of importance to the international projects. Their careful preparation and the proper selection of participants will be essential.

(c) The preparation and publication of encyclopaedic works in the field of earth sciences. This includes the continuation of the "Lexique Stratigraphique International", the speeding-up of the "Lexique Tectonique International" and similar works for petrographic and metallogenic terms.

(d) The intercalibration of methods of analysis and measurement and the technical and financial assistance to developing countries in analysis and determination of specimens. This includes in particular radiometric measurements and palaeontological, micropalaeontological, petrographic and metallogenic determinations.

(e) The co-operation between geological data storage centres, national and international, should be strengthened. The methods for data processing should be unified to the greatest possible extent. The IGCP secretariat should pay special attention to these activities.

(f) The protection of important geological sites, particularly geological types for sites of international importance for the study of geological, biological and human evolution.

VII. PROCEDURES AND MECHANISMS FOR CO-ORDINATION AND IMPLEMENTATION OF THE IGCP

1. Basic principles

To reach the objectives of IGCP, IUGS and Unesco will co-ordinate their activities and implement the programme as a joint venture.

All Member States of Unesco and all member countries of IUGS (i.e. countries where there exists an adhering body of IUGS) will be invited to participate in IGCP.

IGCP is to be viewed primarily as a scientific research programme aimed at improving man's environment and his search for natural resources. The projects that could be included would normally meet the following main criteria:

(a) relevance to the major scientific and practical objectives of the programme;

(b) meet a world-wide, continental or regional need;

(c) preferably involve various branches of geology and their applications and require interdisciplinary co-operation;

(d) require co-ordinated international action and facilitate common understanding between specialists from different countries;

(e) result not only in long-term benefits but also whenever possible yield tangible short-term practical results for the participating countries; this would also lead to an increase in the capabilities of countries less developed in geological sciences.

The programme, while firmly centred on the aims and objectives which have been described above, should maintain a flexibility both in content and approach. It is foreseen that, whereas some projects will become satisfactorily completed others will change in direction, and new projects will be added as and when the need arises.

Though at the present time no definite duration for the programme has been set, it is thought that the main objectives of many IGCP projects can be realized satisfactorily within a period of not more than eight years. After a suitable period of operation - possibly five years - the progress made and the results obtained by IGCP should be reviewed and this might be achieved through holding an international conference similar to the present one. The organizational set-up for the programme is designed for simplicity and efficiency in the evaluation, selection and approval of projects as well as in the assistance and guidance of their implementation. Towards this end, the following bodies should be established: (1) IGCP National Committee; (2) IGCP Board; (3) IGCP scientific committees; (4) an IGCP secretariat; (5) IGCP project working groups.

2. IGCP national committees

The programme is an international undertaking of scientific co-operation among the participating countries. The implementation of the programme is therefore primarily the responsibility of these countries, while the international organizations concerned will provide the necessary stimulation, co-ordination and assistance required for such an undertaking.

In order to ensure maximum national participation in the international programme, to define and implement this national participation and to ensure liaison at the international level, every participating country will be invited to set up or designate an IGCP national committee.

It would be most desirable that national committees of IGCP be constituted - wherever possible - in close consultation with the IUGS national adhering body and the Unesco national commission of the participating country.

The national committee should encourage the active participation in the programme of qualified persons and organizations. The national committee will receive and examine proposals for IGCP projects from national scientific organizations or individual scientists.

Projects which are approved by the IGCP Board will be reviewed by each national committee to determine its country's interest in participation.

Any IGCP national committee can submit to the President of IUGS and to the Director-General of Unesco the name of a candidate for appointment to the IGCP Board.

IGCP national committees should be established as soon as feasible.

3. IGCP Board

An IGCP Board shall be established for the supervision and implementation of the programme within the policy laid down for this programme by Unesco and IUGS.

The IGCP Board shall be composed of:

(1) Fifteen earth scientists appointed by the President of IUGS and the Director-General of Unesco, by mutual agreement, taking due account of scientific competence and of equitable geographical distribution.

(2) Ex-officio representatives of IUGS and Unesco.

The IGCP Board will consider all IGCP project proposals recommended by the IGCP Scientific Committees and will select those which it considers suitable for approval.

Upon IGCP Board approval, a project proposal will become an IGCP project and will be recommended by the IGCP Board to all countries for their consideration.

The IGCP Board will supervise the implementation and progress of each IGCP project; to this end, it will receive and consider progress, activity and final reports.

The IGCP Board will report every two years on the progress of IGCP to the Executive Committee of IUGS and to the Unesco General Conference.

The Draft Statutes for the IGCP Board contained in Annex IV are recommended for adoption by the Unesco General Conference at its seventeenth session and by the IUGS Council at the 24th International Geological Congress.

4. IGCP scientific committees

In order to provide scientific advice to the IGCP Board, scientific committees will be set up consisting of a restricted number of specialists and taking into account the objectives and the content of IGCP.

The number and terms of reference of these scientific committees will be defined by the IGCP Board. The appointment of these specialists will be made by mutual agreement between the President of IUGS and the Director-General of Unesco upon recommendations received from IUGS. The members of the scientific committees may not concurrently serve on the IGCP Board.

The scientific committees will evaluate project proposals in terms of their scientific merit, their financial needs, their economical interest and their appropriateness to the general scope of the programme, and will make recommendations concerning them to the Board. They will also consider the reports of the project working groups and comment on them to the Board.

The scientific committees will take full account of the needs for scientific co-ordination of the projects with any appropriate existing commissions, sub-commissions, committees or working groups of IUGS or its associated organizations, in order to promote effectiveness of results and to avoid undesirable conflicts or duplications. Existing IUGS organizations or associated organizations will be utilized as far as possible, where appropriate, for carrying out IGCP projects.

5. IGCP Secretariat

The Secretariat of IGCP will be a joint responsibility of Unesco and IUGS. It will be located at Unesco Headquarters in Paris in space provided by Unesco. Unesco will provide within the limits

of its possibilities, the necessary staff and services for the Secretariat. IUGS may also provide additional staff and services as it desires.

The Secretariat will ensure appropriate liaison with the national and international bodies concerned with IGCP. It will act as secretariat for the IGCP Board and as a receiving office, clearing house and distribution centre for all IGCP matters. It will also give proper attention to data processing activities.

6. Procedures for project implementation

Draft proposals, which may come from individuals or from national institutions, may be submitted to the respective IGCP national committees.

The national committees will review and evaluate the submitted project proposals and transmit those which they accept as "project proposals" to the Secretariat for evaluation and appropriate consideration by the scientific committees and the Board.

Project proposals may also be submitted by IUGS, its various subsidiary bodies and affiliated organizations (submitted through IUGS) and by Unesco. The Secretariat will keep national committees informed of such proposals.

Each national committee will determine the desirability of participation or non-participation of its country in any IGCP project.

7. IGCP project working groups

Representatives of scientists from the various countries participating in any IGCP project may form a joint project working group.

These working groups will define the scientific aims and the socio-economic objectives of the project and estimate its anticipated duration.

The working groups will organize their own meetings and their secretarial services.

Leaders of the working groups may not also be members of the IGCP Board or the IGCP scientific committees.

Each working group will send to the Secretariat annual activity and progress reports for submission to the scientific committees and the IGCP Board, and will keep the interested national committees informed.

After completion of each IGCP project, working groups should normally prepare final reports for publication as appropriate.

8. Financing of IGCP

Each country participating in an IGCP project will bear the cost of its national participation.

The expenses of working groups for their activities will be met by their respective member countries.

The costs of the IGCP Secretariat with its seat in Unesco House, Paris, secretarial services, including materials, interpretation and translation, documentation, communication and other standard services, will be met by IUGS and Unesco, their respective contributions being the subject of an agreement between them. Conference rooms and facilities in Unesco House, for IGCP bodies, may be made available on request.

Travel expenses (including per diem) of members of the IGCP Board and the scientific committees attending annual meetings will normally be paid by Unesco from its budgetary allocation to IGCP.

Unesco may contribute financially to a limited extent, to the scientific execution of IGCP through contracts related to the execution of certain projects.

IUGS and Unesco will encourage the establishment of post-graduate training courses in specialized fields of the geological sciences for graduates of developing countries participating in IGCP projects.

Unesco may organize with UNDP (United Nations Development Programme) assistance regional training seminars in specialized fields of geological sciences, for graduates or technicians of developing countries who participate in IGCP projects.

The importance of co-ordination with bilateral assistance to developing countries and the major rôle which such assistance can play for successful implementation of IGCP projects has been stressed in earlier parts of this report.

9. IGCP publications

The general subjects to be covered in the publications will be scientific results of IGCP projects, and information regarding development of the programme.

Copies of all publications on IGCP matters should be sent to the IGCP Secretariat for appropriate distribution.

Final results of IGCP projects should be published, using all appropriate channels to this effect.

An IGCP newsletter will be published, using existing periodicals of IUGS and Unesco, and containing in particular activity reports of the scientific committees and the IGCP Board, and activity and progress reports of the IGCP project working groups.

VIII. RELATION OF THE IGCP TO OTHER INTERNATIONAL ORGANIZATIONS AND PROGRAMMES

The Conference considered that close co-operation should be established between IGCP and a number of international organizations, both governmental and non-governmental, and a number of international scientific programmes. At the Conference, some of their representatives indicated interest in the IGCP and stated that their organizations were prepared to contribute to its success.

(a) United Nations organizations

International Atomic Energy Agency - The most exact methods of geochronological dating are based on radioactive decay, and their application commands not only sophisticated laboratory equipment but also highly skilled and experienced scientists. Especially for smaller or developing countries it would be therefore desirable to establish co-operation with IAEA for training purposes and for such services as radiometric age determination of minerals, rocks, soils, and water.

Resources and Transport Division of United Nations - The collaboration with this Division which acts as executing agency of United Nations Development Programme for many development projects in various fields of earth sciences could be very beneficial for IGCP, especially in areas of usually less explored countries. Earth scientists, active in United Nations projects, may be associated with IGCP projects wherever possible, together with their local counterparts.

(b) International non-governmental scientific organizations

International Geographical Union - Some topics of IGCP are of interest to the International Geographical Union (IGU), for example, geomorphological methods of correlation important for dating Quaternary phenomena. Based on the correlation of elevated beach terraces, lake and river terraces, on the orientation and mode of occurrence of accumulated morainal materials, on the occurrence of periglacial phenomena, and other physiographic features, conclusions as to the age of various Quaternary processes can be obtained.

International Union of Geodesy and Geophysics - Geophysical techniques and methods have improved knowledge of deep-seated rock bodies, hidden ore deposits, and deeper parts of the earth's crust. Some of these are already used in geological correlation of various kinds. Of special value for the IGCP is research on magnetism since it may help in clarifying the patterns of planetary processes. Magnetic patterns of the sea floor for instance indicate movements of crustal plates by ocean floor spreading and continental drift and may also help to elucidate the rôle of convection in the mantle. Palaeomagnetic study of rocks is now one of the important methods of geochronological dating. In these, as well as in other fields, the co-operation between the IGCP and the IUGG is most desirable and should lead to scientific achievements of value for both.

Inter-Union Commission on Geodynamics - Various aspects of the Geodynamics Project are related to the IGCP, especially in the fields of tectonics, volcanism, palaeomagnetism and palaeoclimatology.

Tectonic events are closely connected with stratigraphy. They are well recorded in sedimentary sequences and therefore stratigraphical correlation may take into account tectonic phenomena of all kinds.

As strong tectonic activity is concentrated in a few, relatively narrow, mobile belts, most of the present volcanic activity occurs within these belts; these belts comprise the oceanic and continental rift systems, the islands arcs and the young folded mountains. The study and correlation of tectonic phenomena, as well as of accompanying volcanic activity, is also of direct interest to the IGCP.

Similarly research on vertical movements of aseismic continental margins and vertical movements of plateaux and basins will help to elucidate the behaviour of lithospheric blocks. Research of this kind is related to tectonic studies of interest to the IGCP as well as to the geodynamics project. This applies especially to projects dealing with eustatic changes of sea level.

(c) Unesco programmes

Man and the Biosphere - This intergovernmental Unesco programme though dealing primarily with ecological and environmental problems not directly related to geological research, is also linked to some extent with the IGCP. This applies to MAB's study for a better understanding of soil forming processes, of their degradation and restoration in different climatic zones.

Intergovernmental Oceanographic Commission - The IOC has in its programmes many research projects that may become closely connected with the IGCP. These projects include such topics as:

Morphological mapping of the sea floor; systematic geological and geophysical surveys of continental margins; geological and geophysical studies of Mediterranean and marginal seas; river mouth monitoring with emphasis on the nature of suspended materials and waters; deep drilling at key sites in the oceans; detailed studies near crests of the ridge-rift system; meridional profiles of deep ocean sediments; completion of magnetic survey over the world's oceans; manganese nodules and other mineral resources assays; investigation of anomalous deep ocean crustal areas; geotraverses across major crustal features and land-sea geologic transects in critical areas.

Marine geology history needs to be compared with continental geology and this correlation should deepen our understanding of planetary history, including tectonic, climatic and organic evolution from the point of view of land-sea interraction.

International Hydrological Decade (IHD) - Studies being performed by IHD, of special interest for the IGCP are studies on suspended and otherwise carried load in rivers and lakes and its deposition in lakes and other basins; gross sediment transport into the ocean; glacial studies. The study of glaciers is especially appealing to geologists concerned with the geochronology of the Quaternary and with geologic events in Quaternary time. The hydrogeological maps which are sponsored or compiled by IHD are also of value to the IGCP.

Since the Secretariats for the Man and Biosphere Programme, the International Oceanographic Commission and the International Hydrological Decade are also located at Unesco House, co-operation and co-ordination with IGCP should be greatly facilitated.

ANNEX I

Address by
Mr. René Maheu
Director-General of Unesco

Your Excellencies
Ladies and gentlemen,

It is my very pleasant duty to welcome the delegates and eminent specialists who are about to take part here in the work of the Intergovernmental Conference of Experts for preparing an International Geological Correlation Programme.

Convened in pursuance of resolution 2.321 (a), adopted by the General Conference at its sixteenth session, this is, so far as I know, the first intergovernmental meeting to deal exclusively with geological problems. Yet geology is, by its very nature, an obvious subject for international study and geologists were among the first in the scientific community to organize regular exchanges of knowledge and information. International geological congresses, indeed, have been taking place for almost a century already, leading to the setting up of many permanent associations in various branches of this science. But it is perhaps precisely because such excellent scientific co-operation had thus been established among geologists that it was so long before the need to institutionalize it and to create new structure for the purpose was felt.

Thus it was not until 1961 that the International Union of Geological Sciences was founded. Since then, Unesco has maintained particularly cordial and fruitful relations with the Union. And I am very pleased to see Professor Dunham, its President, Mr. van der Heyde, its Secretary-General, as well as members of its Executive Committee and other bodies, with us here today.

In fact, it was not until fairly recently that it was realized how much could be gained by organizing intergovernmental co-operation in connexion with geology. The Conference opening today will give you an opportunity of taking full advantage of the possibilities existing in this respect.

The purpose of this Conference is to define the content of an international geological correlation programme and the procedures for carrying it out, with the idea that it may be adopted and launched by the General Conference of Unesco, at its seventeenth session, in October 1972. To fulfil this purpose, you will be able to draw on the results of the preparatory work carried out for you, in particular at the meeting of experts which Unesco organized at Budapest in September 1969, in close co-operation with the International Union of Geological Sciences. This meeting and the consultations which have since taken place both with Member States and with the representatives of the scientific organizations concerned have made it possible to prepare the working papers submitted to you as a basis for discussion.

Some people may think that we have been rather too slow in launching an international programme in geology, and the painstaking preliminary work to which I have just referred may have made some scientists a little impatient. It is true that intergovernmental programmes take rather a long time to come to fruition but that is the price that has to be paid for securing government support. Furthermore, geology has had to take its place among the other subjects of study calling for a concerted world effort. I think, however, that, when all is said and done, we have been well advised not to rush matters. From what the specialists have told me, accepted ideas on the formation and evolution of the earth's crust have changed radically in the course of the past few years. For instance, the geophysical data yielded by seismological and geomagnetic studies, inter alia, have led to the emergence of new ideas about the tectonics of the globe. Ocean floor spreading now seems to be an established fact, while the plate tectonics theory throws a new light on the old hypothesis of continental drift.

These advances in our knowledge of the dynamics of the earth's crust should be of considerable help to geologists in fulfilling one of their oldest ambitions, namely, the establishment of a geological time scale valid for the whole earth. They should also enable them to arrive at a better understanding of geological events themselves. There is no need to draw your attention to the beneficial effects which such a development would be bound to have on most branches of geology and, in particular,

on our understanding of the processes involved in the genesis and distribution of minerals which are of great economic interest. Yet if these new ideas are to lead on to tomorrow's geological discoveries, geologists will have to apply themselves straight away to developing the correlation of data and information concerning the various regions of the world and the great events which have shaped the crust of our planet. This is, in fact, the main aim of the programme which you are asked to work out.

The establishment of such a programme also seems timely for other important, though not strictly scientific, reasons. On the one hand, many governments are rightly concerned at the intensive exploitation of mineral resources and the danger of running short of some of them in the relatively near future. On the other hand, the international monetary crisis and the evolution of the world economic situation undoubtedly portend serious difficulties in regard to the financing of scientific research throughout the world, and to co-operation between developed and developing countries, unless steps are taken promptly. These considerations, it seems to me, should not be far from your minds as you proceed with your work.

In particular, I think that you will wish to work out an International Geological Correlation Programme which will not be an unduly rigid catalogue of activities to be followed strictly in the coming years, but rather a realistic overall plan taking account of the interests and resources of the governments and other bodies called on to bear the cost of carrying out the Programme. You will also, I am sure, take care to see that each country, great or small, rich or poor, feels involved in the Programme and can play its part in it. Lastly, you will be careful to harmonize this new intergovernmental programme with those other international programmes which have already been undertaken in the earth sciences.

While your work will bear mainly on the content of the future programme, you will also have to specify how it is to be organized and the general procedures for its execution. The latter will, of course, have to preserve and safeguard the intergovernmental character of the programme, in that each participating government will have to undertake to play its part in carrying it out effectively. The system suggested to you, however, is substantially different from the one adopted by Unesco for its major international programmes on oceanography, hydrology, and man and the biosphere. In these three cases, the General Conference felt it necessary to set up intergovernmental co-ordinating bodies. In the case of the programme with which you are concerned, it was thought preferable to devise a solution which would take account both of the long tradition of international co-operation of which geologists are so properly proud, and of the important part that the International Union of Geological Sciences will be called upon to play in carrying out such a programme. It is accordingly suggested that responsibility for the planning and general co-ordination of the International Geological Correlation Programme should rest with a Board of distinguished geologists from different countries, appointed jointly by the Director-General of Unesco and by the President of the Union. The arrangement is unusual, but would seem to be practical. You will, I am sure, consider its various aspects very carefully.

The Secretariats of Unesco and of the International Union of Geological Sciences have worked in concert in preparing the documents intended for your use in outlining an International Geological Correlation Programme. But the General Conference of Unesco and the Council of the Union will, of course, have to adopt the Programme that you recommend to them at the close of this meeting. And, in the last analysis, it will rest with the geologists of all countries to make sure that this new and exciting venture in international scientific co-operation succeeds in practice.

Bearing all this in mind, I offer you, ladies and gentlemen, my warmest good wishes for the success of your work.

ANNEX II

Speech by
Professor Kingsley Dunham
President, International Union of Geological Sciences

Your Excellencies
Ladies and gentlemen

First let me thank you warmly, Mr. Director-General, for the cordial sentiments you have expressed towards geologists and the earth sciences. The members and officers of the International Union of Geological Sciences are very grateful for your kind welcome. Personally, I very much appreciate the opportunity to speak at this early stage for I come not as a delegate of my country, but in a sense as an observer for the Union which, should our deliberations be successful, will be a partner in this world-wide enterprise.

The International Union of Geological Sciences, founded in 1961 inherited from the long series of International Geological Congresses, extending back over nearly a century, a number of important commissions. Several of these are highly relevant in the present context, notably the Commission on Stratigraphy whose president, Professor Menner (USSR) I am very glad to see with us this morning. The Commission has experienced some unfortunate handicaps in recent years; for example during the 1964 International Congress in India, many of its members who had been attending an excursion in Kashmir had the misfortune to be prevented from reaching the Commission meetings because of early snow in the mountains; while in 1968 unhappy events in Prague disrupted its work. Nevertheless, it has a series of highly active sub-commissions, for example that dealing with the Precambrian, led by Professor Rankama (Finland) and that on the Siluro-Devonian boundary under Dr. MacLaren (Canada). The Sub-Commission on Stratigraphical Nomenclature of which Professor Hedberg (U. S. A.) is president has more than fifteen years of continuous work behind it and next year is expected to publish a significant report aimed at general standardization.

In the case of the IUGS Commission on the Geological Map of the World, with which Professor Marcais (France) has long been associated, there is already a good tradition for collaboration with Unesco. This has been very fruitful, as the beautiful maps so far published bear witness. The preparation of the World and European maps, the tectonic, metallogenic and metamorphic maps all throw up problems of correlation. It may safely be said that this valuable commission could not have functioned but for the generous support provided by Unesco.

The past two decades have produced a vast explosion of geological data. Fundamental research, as well as a research for fuels and minerals on an unprecedented scale has resulted from the faith of mankind that the science can help to meet its growing need for raw materials and for a favourable environment. Funds to pay for the investigations have come from governments, through national geological surveys and state-owned industries, from private companies, from universities and not least through the UNDP Special Fund. The Special Fund has been widely applied in developing countries, and bilateral aid projects have also been active in many such countries. Here I speak with considerable personal experience, for over the past few years I suppose I have visited almost half the developing countries here represented. Notwithstanding the good work of the existing IUGS commissions and affiliated organizations, it is evident to all who are familiar with the scene that there is great need to bring the data of the earth sciences into a proper state of correlation on a fully international scale. It is reasonable to believe that this would have significant practical results. The International Geological Correlation Programme has been designed to achieve this.

The possibility of joint action between IUGS and Unesco was first discussed as long ago as 1964. In 1967, at Prague, form was given to the proposal by a meeting which included Professor Hedberg (in the chair), Dr. Walter (Unesco), Miss Delany (France), Professor Zoubek (Czechoslovakia), Professor Glaessner (Australia), Mr. Harland (U. K.), Professor Zhamoidea (USSR), and Professor van Leckwijck (IUGS). The IUGS Council in 1968 welcomed the proposal and early in 1969 its Executive Committee voted in favour of collaboration with Unesco by a large majority. The meeting of experts to draft a preliminary progamme sponsored by Unesco was held later that year in Budapest. By that time it was becoming apparent that the scale of the programme would make intergovernment approval necessary and that since Man and the Biosphere was in the queue ahead of

IGCP, the Correlation Programme could not be put to the Unesco General Conference until 1972. The IUGS Executive Committee accordingly decided to launch a programme with the limited resources at its disposal and form a co-ordinating panel for this purpose. Thus, from the point of view of IUGS, an International Correlation Programme is in being, 14 projects having been accepted. If a joint operation with Unesco becomes possible, as the Executive Committee earnestly hopes, this small programme would merge into the larger scheme, and its panel could well evolve within the scheme.

On behalf of the International Union, I express my gratitude to all the delegates of governments who have given their time to come to Paris to attend this meeting, which may well prove to be an historic milestone in the earth sciences.

ANNEX III

MAJOR CORRELATION PROBLEMS ARRANGED CHRONOLOGICALLY

THE PRECAMBRIAN

The Precambrian covers some 85% of the total length of geological time. Precambrian rocks either outcropping or covered by a thin layer of younger sediments occur abundantly on all continents, but, when studying them, their scarcity of fossils and their altered nature pose special problems.

Research on the Precambrian is, at the same time, very important for general and applied geology alike, since the Precambrian contains the largest and richest deposits of many metals.

A more complete knowledge of the age of economic deposits in the Precambrian will allow evaluation of large areas, the richness of whose mineral wealth is only now beginning to be known, in South America, Africa, the Indian Peninsula and Australia, and more particularly, in the developing countries of those regions. Such studies might, for example, serve as the basis for a search for oil in the Upper Precambrian, as in the USSR and Australia.

For those reasons, stratigraphic, palaeogeographical, petrological and metallogenetic research in the Precambrian may provide the solution to more general geological problems. Numerous regional stratigraphic scales exist for the Precambrian but there is no generally agreed global scale, Such a great scale needs to be established. To do this requires the utilization of existing biostratigraphic and physico-chemical methods, which would have to be adapted and transformed for Precambrian research. Such adaptation could only be really effective if it is carried out on an international basis.

1. Methods

(a) Radiometry and petrography. Among the world-wide correlation methods for the Precambrian, particular importance should be given to radiometric dating and petrography. It would seem advisable to apply these techniques in defining the sub-divisions of the Precambrian, to the tectonic-plutonic cycles, chosen in those special regions where such cycles can be well-defined geologically.

(b) Palaeomagnetism. Palaeomagnetic studies based on changes in the geomagnetic field may also afford a possibility for the stratigraphic correlation of the younger Precambrian on a global basis.

(c) Biostratigraphy. The research for early life in the Precambrian now indicates that primitive life on the earth existed more than 3,000 million years ago. Research on formations containing plant fossils, such as stromatoliths or acritarchs, provides the first possibilities for long-range correlations in the Upper Precambrian.

(d) Geochemistry and stable isotope methods. It can also be expected that new geochemical discoveries will open up possibilities for establishing correlations in the Early Precambrian.

2. Problems

(a) Evolution of the atmosphere. The use of palaeoclimatologic evidence for stratigraphic purposes in the Precambrian appears particularly promising in regard to the constitution of the atmosphere, which was the controlling factor in lithogenesis and metallogenesis during the Early Precambrian. The difficult problem of the origin of photosynthesis in the Precambrian should also be tackled.

(b) Red formations. Another important problem which must be taken into account is that of residual formations and the red beds in the Late Precambrian.

(c) Ice ages. The world-wide occurrence of tillites at the summit of the Precambrian and at the base of the Cambrian deserves particular attention, as much from the palaeoclimatologic as from the stratigraphic angle.

(d) Precambrian oceans. The volume and the chemical compositions of the early ocean, and the formation of the first phosphate and sulphate sediments is a subject involving not only general geology (palaeoclimatology, palaeoceanology, palaeogeochemistry) but - and above all - applied geology, from the point of view of the genesis of sedimentary mineral deposits.

(e) Evolution of the Solar System. The study of the Precambrian is certainly closely related in many respects to that of the cosmic life of the planet. For example, the evolution in the relationship between the earth and the moon, or between the earth and the rest of the solar system, which is a major scientific problem today, may have left traces in the Precambrian rocks, study of which may bring information to light on this subject.

THE PHANEROZOIC (QUATERNARY EXCLUDED)

The long time span of the Phanerozoic, with its diversity of deposition, volcanic activities deformational processes, metamorphism and metallogenic processes, offers many major problems still awaiting their final solution.

1. Methods

The Palaeozoic, the Mesozoic, and the Tertiary represent the main period of development of different methods of stratigraphic correlation. The general outline of the established time-scale is more than a century old. The clear relationship between the distribution of fossils and sedimentary events has made it possible to use biostratigraphy as an approximation to chronostratigraphy. There is, however, the need for a considerable development of the methods of treating organism communities on an ecostratigraphic basis to consolidate and refine the relative datings based on the different facies of one or a few fossil groups only. The integration of these methods of correlation with the absolute time scale, e. g. , by radiometric and palaeomagnetic dating is as important as the primary application of the latter methods where biostratigraphic evidence is not available.

Tectonic events in the older Phanerozoic area often well dated and closely correlated with sedimentation and organic evolution: hence the results of Phanerozoic tectonics are a prerequisite for the understanding and the correlation of the equivalent phenomena in the Precambrian and their correlation in the sense of the IGCP. Refined regional correlation is essential for the understanding of orogenesis and the associated genesis of mineral deposits. The development area for the methods is mainly in the Phanerozoic.

2. Practical applications

Economic applications of the methods of correlation are in the Pre-Quaternary Phanerozoic dominated by the importance of petroleum and gas geology, where the economic consequences of refined correlation are often spectacular and not uncommon. Exploration for further resources of hydrocarbons is becoming increasingly dependent on palaeogeographic analyses which requires time correlations to an extent far beyond what has hitherto been assumed. Nuclear fuels are to a considerable extent found in the Phanerozoic. Other energy resources, such as coal and oil shales, might have to be reconsidered for economic use in the not too distant future, and refinement of correlation and correlation methods can help us to do this more quickly and at lower cost. Detailed correlation of all parts of the Phanerozoic is of equal importance for the exploitation of salt deposits, including, e. g. phosphatic fertilizers, and raw materials in engineering construction.

3. Standards

The work on standards in stratigraphy, such as stratotypes and a stratigraphical terminology, is very largely carried out in the Pre-Quaternary Phanerozoic. The great importance of these standards in a variety of kinds of geological activity is illustrated elsewhere in this document.

THE QUATERNARY

About two million years ago the earth's climate entered on a period of marked instability, and the Quaternary Era opened at the first record of climatic deterioration in temperate latitudes. Great ice-caps formed repeatedly in many parts of the world, and as the ice advanced and retreated it transported and deposited vast quantities of material. In other parts of the world, climate changed into more humid or more arid conditions than at present.

1. Deposits and correlation methods

The correlation of glacial, periglacial and pluvial deposits from continent to continent is an important task for stratigraphy. Many of the deposits are coarse in grain and capable of holding large quantities of water. Such supplies of groundwater are of great economic significance.

As Quaternary deposits are often not indurated, they offer problems in city planning and engineering construction. On the other hand, an important part of the raw materials for building purposes is derived from these deposits.

2. Soils

Soils, the earth's most important economic deposit, are developed in large part on Quaternary materials. Unlike minerals, they need not be exhausted by exploitation, and their proper management is vital to mankind. Current knowledge of soils is not enough directed towards the geological aspect, and there must be major programmes into the genesis and distribution of soils, both palaeosols and recent soils. Study of interglacial palaeosols which were not disturbed by human activity can throw much light on modern soil development. Study of interglacial and Tertiary weathering could show how secondary enrichment of ores took place in older geological periods.

3. Climate

The glacial and interglacial stages and their impact on the animal and plant world have provided us with the best tool to decipher the stratigraphy of Quaternary deposits.

The current warm stage opened about 10,000 years ago, and has been marked by climate fluctuation. Seven thousands years ago the climate was warmer than today, while about 2,500 years ago the weather was cooler. The climate was warm again about 800 years ago, and then there was a "little ice age" from about 1550 to 1850 A. D., and expanding glaciers covered cultivated land. A century of warmer weather followed, but since 1940 deterioration has been detectable in some parts of the world. In most parts of the world, however, climate changes have not been studied and correlated.

4. Sea level

Sea level is related to the amount of ice present on land, and thus is climate. There have been changes in level throughout the Quaternary, and if all the ice on earth were to melt the sea would rise by 50 m. with catastrophic results for large areas of low-lying densely populated lands. Large inland lakes, such as those of North America and Africa, are also sensitive to changes in climate. Even small changes in water level are important to city planning, harbours, etc.

5. Landforms

Landforms are of essential importance for land use as well as for rural and urban planning, particularly with regard to the less developed countries. Most landforms obtained their final shape during the Quaternary Period. Correlation, description, and cartographic representation of landforms are of particular importance for the present and the future of human activity.

Conclusion

Governments responsible for planning a world that is about to be overcrowded cannot ignore possible changes in climate and in sea level. Through a major international programme IGCP must collect all the evidence that will reveal the changes in climate of the recent past, endeavour to establish the causes underlying these changes, and armed with this knowledge make predictions of future short-term climatic changes, to the immense benefit of mankind.

ANNEX IV

PROPOSED STATUTES OF THE BOARD FOR THE
INTERNATIONAL GEOLOGICAL CORRELATION PROGRAMME
(HEREAFTER CALLED THE "IGCP")

Article 1

1. A Board for the International Geological Correlation Programme, is hereby set up.

Article 2

2. 1 The Board shall be composed of 15 members appointed by the President of IUGS and the Director-General of Unesco by mutual agreement.

2. 2 Names of candidates for the Board are submitted to the joint Secretariat by the IGCP National Committees.

2. 3 The members appointed to the Board shall be persons actively engaged in scientific research related to the objectives of IGCP, taking into account an equitable geographical distribution.

2. 4 Each appointed member shall have one vote.

2. 5 Voting members of Board shall be eligible for reappointment but shall not remain in office continuously for more than 6 years.

2. 6 The appointment of the voting members of the Board shall be made every two years. (Taking into account both the need for continuity and the need for rotation of membership.)

2. 7 The Secretary-General of IUGS and a representative of the Director-General of Unesco shall be ex-officio members of the Board but without voting privileges.

Article 3

3. 1 The Board shall meet at least once a year.

3. 2 The annual meetings may be attended by observers of interested international scientific organizations, including the IGCP Scientific Committees.

3. 3 Representatives of the United Nations and other intergovernmental organizations and of member countries of IGCP shall be admitted to the Board meetings as observers.

3. 4 Observers shall not have voting privileges.

Article 4

4. 1 At its first session the Board shall elect a Chairman and two Vice-Chairmen. These shall form the Board's Bureau.

4. 2 The Board shall elect a new Bureau whenever its own membership is changed in accordance with Article 2, paragraphs 2. 1 to 2. 6. Members of the Bureau are eligible for re-election.

4. 3 The Board's Bureau may be convened between the Board's annual meetings.

4. 4 The Board shall adopt its own rules of procedure.

Article 5

5.1 The Board shall be responsible for supervising, from the organizational and from the scientific points of view, the implementation of IGCP, for studying proposals concerning developments and modifications of the programme, for recommending scientific projects of interest to IGCP member countries, for co-ordinating international co-operation in the framework of IGCP, for assisting in the development of national and regional projects related to IGCP and for taking any measures that may be required for the successful implementation of the Programme.

5.2 In carrying out its activities, the Board may make full use of the facilities offered by IUGS, Unesco, other international organizations, governments and foundations.

5.3 The Board may consult on scientific questions all appropriate international or national governmental or non-governmental scientific organizations and, in particular, the International Council of Scientific Unions (ICSU).

5.4 The Board shall, whenever possible, co-ordinate IGCP with other related international scientific programmes.

Article 6

6.1 The Board is assisted in its scientific duties by Scientific Committees established for this purpose jointly by IUGS and Unesco.

6.2 The Board defines the number and terms of reference of the Scientific Committees which have to evaluate project proposals in terms of their scientific merit, their financial needs, their economical interest and their appropriateness to the general scope of the programme, and to make recommendations concerning them to the Board.

6.3 The Board may assign to its own Bureau certain duties, as for instance the approval of reconsidered and modified IGCP project proposals or the approval of the annual progress reports of IGCP project working groups or the approval of revised final reports of IGCP projects.

Article 7

7.1 The IGCP Secretariat shall provide the necessary secretarial services for all meetings of the Board.

7.2 The IGCP Secretariat shall take the steps required to convene the meetings of the Board.

Article 8

8.1 The Board's Bureau shall prepare annual activity reports of the Board for publication.

8.2 The Board shall prepare a report every two years on the progress of IGCP for the Executive Committee of IUGS and for the Unesco General Conference.

8.3 The Board may suggest changes of the policy, scope or organization of IGCP, to the President of IUGS and to the Director-General of Unesco for their consideration.

ANNEXE/ANNEX/ANEXO/ПРИЛОЖЕНИЕ V

LISTE DES PARTICIPANTS/LIST OF PARTICIPANTS
LISTA DE PARTICIPANTES/СПИСОК УЧАСТНИКОВ

Names and titles in the following lists are reproduced as handed in to the Secretariat by the delegations concerned. Countries are shown in the French alphabetical order. (An asterisk indicates the head of the delegation.)

Les noms et titres qui figurent dans les listes ci-après sont reproduits dans la forme où ils ont été communiqués au Secrétariat par les délégations intéressées. Les pays sont mentionnés dans l'ordre alphabétique français. (Un astérisque indique le chef de délégation.)

Los nombres y títulos que figuran en las listas siguientes se reproducen en la forma en que las delegaciones interesadas los han communicado a la Secretaría. Los países se mencionan en el orden alfabético francés. (Un asterisco indica el jefe de la delegación.)

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ANNEXE/ANNEX/ANEXO/ПРИЛОЖЕНИЕ V

LISTE DES PARTICIPANTS/LIST OF PARTICIPANTS
LISTA DE PARTICIPANTES/СПИСОК УЧАСТНИКОВ

I. ETATS MEMBRES/MEMBER STATES/ESTADOS MIEMBROS/ГОСУДАРСТВА-ЧЛЕНЫ

ALGERIE/ALGERIA/
ARGELIA/АЛЖИР

Mr. Omar Merabet
Chef du Service géologique au Ministère de
l'industrie et de l'énergie scientifique
Alger

Mr. Mohamed Tasiani
Chef du Département des sciences de la terre
au Ministère des sciences et de la recherche
scientifique
Alger

REPUBLIQUE FEDERALE D'ALLEMAGNE/
FEDERAL REPUBLIC OF GERMANY/
REPUBLICA FEDERAL DE ALEMANIA/
ФЕДЕРАТИВНАЯ РЕСПУБЛИКА ГЕРМАНИИ

Professor Dr. H.K. Erben
Institut für Paläontologie,
Universität Bonn,
Nussallee - 8

Professor Dr. R. Vinken
Bundesanstalt für Bodenforschung
Hannover, Stilleweg - 2

Dr. I. Wendt
Bundesanstalt für Bodenforschung
Hannover, Stilleweg - 2

Professor Dr. K. von Gehlen
Institut für Petrologie, Geochemie und
Lagerstättenkunde der Universität Frankfurt
Frankfurt - D-6

Professor Dr. Ing. Albrecht Wilke
Institut für Lagerstättenforschung und
Rohstoffkunde der TU Berlin

Dr. H. Glashoff
Bundesanstalt für Bodenforschung
Hannover, Stilleweg - 2

Professor Dr. A. Siehl
Geologisches Institut des Universität
Bonn, Nussallee - 8

Professor Dr. H. Tobien
Paläontologisches Institut
Universität Mainz

Professor W. Ziegler
Geologisch-Paläontologisches Institut
Universität Marburg
355 Marburgilahn
Deutschhausstr. 10

ARABIE SAOUDITE/SAUDI ARABIA/
ARABIA SAUDITA/САУДОВСКАЯ АРАВИЯ

Dr. F. K. Kabbani
Deputy Min. for Mineral Resources
P. O. Box 345
Jeddah

ARGENTINE/ARGENTINA/АРГЕНТИНА

Dr. W. R. Burghardt
Ministro Consejoro
Délégation permanente de l'Argentine
auprès de l'Unesco

Dr. H. H. Camacho
Consejo Nacional de Investigaciones
Científicas y Técnicas
Buenos Aires

Dr. Emilio F. Gonzáles Diaz
Dirección Nacional de Geología y Minería
Buenos Aires

AUSTRALIE/AUSTRALIA/АВСТРАЛИЯ

Dr. N. H. Fisher
Director, Bureau of Mineral Resources,
Geology and Geophysics
Canberra - ACT

AUTRICHE/AUSTRIA/АВСТРИЯ

Dr. K. Metz*
Geologisches Institut
Universität Graz
Graz - A. 8010

Professor Dr. Ing. Felix Herman
Institute for Prospecting Exploration
and Mineral-Economics Mining
Metallurgy University
Leoben

Dr. H. Holzer
Chief Geologist
Geological Survey of Austria
Vienna - 3

BELGIQUE/BELGIUM/BELGICA/БЕЛЬГИЯ

S. Exc. le Baron Papeians de Morchoven
Ambassadeur, délégué permanent de la
Belgique auprès de l'Unesco

Mr. André Delmer
Chef du Service géologique de Belgique
16 avenue Colonel Daumerie
Bruxelles - 1160

Professeur P. Evrard
Secrétaire général de l'AIVCIT
Institut de géologie
45 avenue des Tilleuls - B. 4000
Liège

Dr. Jean Michot
Professeur à l'Université de Bruxelles
Bruxelles

Professeur Paul Michot
Membre de l'Académie des sciences,
Professeur à l'Université de Liège
88, rue Henri Vieux temps
Liège

Mr. A. van den Driessche
Délégation permanente de la Belgique
auprès de l'Unesco

Professeur W. P. van Leckwijck
Past Secretary-General IUGS
Nechelsesteenweg, 206
Anvers - 2000

Professeur P. Macar
Avenue du Mémorial, 4
Sclessin
Ougree - 4200

REPUBLIQUE SOCIALISTE SOVIETIQUE DE
BIELORUSSIE/BYELORUSSIAN SOVIET
SOCIALIST REPUBLIC/REPUBLICA SOCIALISTA
SOVIETICA DE BIELORRUSIA/БЕЛОРУССКАЯ
СОВЕТСКАЯ СОЦИАЛИСТИЧЕСКАЯ РЕСПУБЛИКА

Dr. V. A. Kouznetsov
76 Lenin Avenue, apt. 84
Ninsk

BRESIL/BRAZIL/BRASIL/БРАЗИЛИЯ

Professeur F. F. M. de Almeida
Ecole polytechnique de São Paulo
São Paulo

Mr. L. Ph. De Macedo Soares Guimarães
Délégation permanente du Brésil auprès
de l'Unesco

BULGARIE/BULGARIA/БОЛГАРИЯ

Professor I. Kostov*
Professor at the University of Sofia
Department of Mineralogy
Boulv. Russki - 15
Sofia

Professor V. Tzankov
University of Sofia
Department of Palaeontology
Boulv. Russki - 15
Sofia

Professor Dr. B. Bogdanov
Director of Geological Institute
Kv. Geo Milev, ul. 36
Sofia XIII

Dr. I. Sapunov
Senior Scientific Collaborator
Geological Institute
Kv. Geo Milev, ul. 36
Sofia XIII

BURUNDI/БУРУНДИ

Mr. A. Ndenzako
Directeur des mines et de la géologie
B. P. 745
Bujumburq

CANADA/КАНАДА

Dr. S. C. Robinson*
Chief, Economic Geology and Geochemistry Division
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario

Dr. D. J. McLaren
Director, Institute of Sedimentary and Petroleum Geology,
3303 - 33rd Street N. W.
Calgary - Alberta

Professeur Dr Roger A. Blais
Directeur de la Recherche
Ecole Polytechnique,
Université de Montréal
Montréal

Dr. M. Tremblay
Consulting Geologist
Québec P. Q.

Dr. A. Sutherland Brown
Deputy Chief, Mineralogical Branch
Department of Mines and Petroleum Resources
Victoria

REPUBLIQUE CENTRAFRICAINE/CENTRAL AFRICAN REPUBLIC/REPUBLICA CENTROAFRICANA/ЦЕНТРАЛЬНОАФРИКАНСКАЯ РЕСПУБЛИКА

Mr. A. Gassimbala
Ingénieur des mines
Directeur des mines de la République centrafricaine

CHINE/CHINA/КИТАЙ

S. Exc. Mr. Chi-Ching Yao
Ambassadeur, délégué permanent de la République de Chine auprès de l'Unesco

Professor Ting-Yinth Ma
Professor of National Taiwan University

Dr Hsien Ho Tsien
Chercheur à l'Université de Taiwan

DANEMARK/DENMARK/DINAMARCA/

Dr. Ian Bondam
Delegate for the Danish Unesco Commission and for Danish National Commission for Geology
Geological Survey of Greenland

Professeur Nils Spjeldnaes
Professeur de géologie chronologique
Geologisk Institut Aarhus Universitet
DK - 8000 Aarhus

REPUBLIQUE DOMINICAINE/DOMINICAN REPUBLIC/REPUBLICA DOMINICANA/ ДОМИНИКАНСКАЯ РЕСПУБЛИКА

S. Exc. M. Federico-Máximo Smester*
Ambassadeur
Délégué permanente de la République dominicaine auprès de l'Unesco

Mr. Jose-Luis Mercé-Platero
Secrétaire de la délégation permanente de la République dominicaine auprès de l'Unesco

ESPAGNE/SPAIN/ESPAÑA/ИСПАНИЯ

Professor José María Fuster Casas*
Directeur de l'Institut de recherches géologiques de Madrid

Dr. Salvador Reguant Serra
Scientific Adviser of Instituto Jaime Almera de Investigaciones Geológicas (CSIC) Université Barcelona

Dr. Manuel Alvarado Arrillaga
Geological and Mining Institute of Spain

Dr. F. De Pedro Herrera
Investigador de la Junta de Energía Nuclear

ETATS-UNIS D'AMERIQUE/UNITED STATES OF AMERICA/ESTADOS UNIDOS DE AMERICA/ СОЕДИНЕННЫЕ ШТАТЫ АМЕРИКИ

Professor H. D. Hedberg*
Professor of Geology
Princeton University
118 Library Place
Princeton, N. J. 08540

Dr. A. T. Miesch
Geologist, US Geological Survey
Denver, Colorado 80225

Dr. Ph. W. Guild
Geologist, US Geological Survey
Washington,DC 20242

FINLANDE/FINLAND/FINLANDIA/ФИНЛЯНДИЯ

Professor Dr. H. Stigzelius*
Director of the Geological Survey of Finland
Angskulla 7-C
Niittykumtu

Professor Dr. Kahma
Chief of Exploration, Department
Geological Survey of Finland
Mantytiita 9-C
Tapiola

Dr. A. Vorma
Secretary of the Finnish
National Committee for Geology
Geological Survey of Finland
Otaniaman AS. SAAT. 2-A
Otaniani

Miss Anja-Riita Ketokoski
Deputy Permanent Delegate to Unesco

Professor Ahti Simonen
Head of Petrological Department
Geological Survey of Finland
Otakallio - 6-D
Otaniani

FRANCE/FRANCIA/ФРАНЦИЯ

M. Jean Marçais*
Directeur scientifique au CNRS
15 Quai Anatole France
Paris VII

M. Jean Coulomb
Professeur de physique du globe
Académie des sciences
4, Rue Emile Dubois
Paris XIV

Professeur Robert Laffitte
Professeur au Muséum national
d'histoire naturelle, président du
Comité national français de géologie
61, Rue de Buffon
Paris V

Professeur Pierre Laffitte
Ingénieur en chef des Mines
60, Boulevard St.-Michel
Paris VI

Professeur M. Roques
Professeur de géologie à l'Université
de Clermont-Ferrand
5, Rue Kessler
Clermont-Ferrand (63)

Professeur Dr C. Guillemin
Directeur du Service géologique national
au BRGM
74, Rue de la Fédération
Paris XV

Professeur Georges Aubert
Professeur des sciences du sol
Chef de service à l'ORSTOM
24, Rue Bayard
Paris VIII

M. Jacques Landry
Chef de bureau, affaires scientifiques,
Ministère des affaires étrangères
Quai d'Orsay
Paris VII

M. Léon Delbos
Chairman,Committee of Geological
Documentation, IUGS
74, Rue de la Fédération
Paris XV

M. Francis Hahn
ENSMD
60, Boulevard St.-Michel
Paris VI

Professeur P. Nicolini
Chef du Département de géologie minière
9, Avenue des Etats-Unis
Pau (64)

M. Jean H. Ricour
Directeur adjoint du Service géologique
national
74, Rue de la Fédération
Paris XV

Dr Maurice Slanski
Chef du Département de géologie
Service géologique national, BRGM
BP. 6009
Orléans (45)

M. Philippe Wacrenier
Conseiller aux programmes du BRGM
74, Rue de la Fédération
Paris XV

GABON/ГАБОН

M. P. Ampamba Gouerangue*
Directeur des mines et de la géologie
du Gabon
Ministère des mines et de l'énergie
Libbreville

M. Michel Karlin
Chef du Service géologique du Gabon
Ministère des mines et de l'énergie
Libbreville

GUATEMALA/ГВАТЕМАЛА

Mr. Oscar Bertholin y Galvez
Permanent Delegate of Guatemala to
Unesco

HONDURAS/ГОНДУРАС

S. Exc. Professor Dr. C. Deambrosis Martins
Délégué permanent du Honduras auprès
de l'Unesco
Ministre plénipotentiaire

HONGRIE/HUNGARY/ HUNGRIA/ВЕНГРИЯ

Professor Dr. E. Nemecz*
Rector of the Veszprén Chemical University
Ñllöi 101
Budapest X

Professor Dr. Mrs. M. Fölvári
Head, Department of the Hungarian
Geological Institute
Népstadion üt 14
Budapest XIV

IRAK/IRAQ/ИРАК

Mr. Safa Al-Din Tarid
Head of Geology Department
College of Science
Baghdad University
62-2-1 Rawaaf Street
Sadoon, Baghdad

IRAN/ ИРАН

Dr. F. Bozorgnia*
Head of Geological Laboratories of the
National Iranian Oil Co.
P. O. Box 1516

Dr. Professor A. Kimyai
Department of Geology
Faculty of Science
Teheran University

Dr. M. Davoudzadeh
Chairman, Department of Exchange of
Geological Information
Geological Survey of Iran
P. O. Box 1964
Teheran

IRLANDE/IRELAND/IRLANDA/ИРЛАНДИЯ

Dr. C. Williams*
Director, Geological Survey of Ireland
14 - Hum Street
Dublin - 2

Professor C. H. Holland
Department of Geology
Trinity College
Dublin - 2

ISRAEL/ИЗРАИЛЬ

Mr. E. Zohar *
Director, Geological Survey of Israel
Jerusalem

Mr. M. Raab
Head, Paleontological and Stratigraphical
Division, Geological Survey of Israel
45, Tchernihovsby Street
Jerusalem

ITALIE/ITALY/ITALIA/ИТАЛИЯ

Professor G. B. La Monica
Secretary of IUGS
National Committee
Ist. di Geologia
Universita di Roma

Professor A. Iacobacci
Service géologique, Ministère de
l'industrie et du commerce
Roma

Dr. G. L. Del Bono,
Service géologique, Ministère de
l'industrie et du commerce
Roma

Dr. L. Pannuzi
Service géologique, Ministère de
l'industrie et du commerce
Roma

JAPON/JAPAN/ЯПОНИЯ

Professor Dr. T. Tatsumi*
Faculty of Science,
University of Tokyo

Professor Dr. A. Morishita
Faculty of Science
Nagoya University

LIBERIA/ЛИБЕРИЯ

Dr. A. E. Nyema Jones*
Chief, Liberian Geological Survey
P. O. Bag 9024, Monrovia

Mr. Bismarck R. Cooper
Geologist, Liberian Geological Survey
P. O. Bag 9024, Monrovia

MEXIQUE/MEXICO/МЕКСИКА

Mr. Guillermo P. Salas*
Director General del Consejo de
Recursos Naturales no Renovables
Sierragorda N° 12
México, 10 D. F.

Mr. Diego A. Córdoba
Director del Instituto de Geología de la
Universidad Nacional Autónoma
de México
México, 20 D. F.

Dr. N. Héroes Navarro
139 Col. Doctores
CRNNR - México, 7 D. F.

MONACO/МОНАКО

Captain L. Grinda
Directeur de l'observatoire de séismologie
et de météorologie
Avenue St.-Martin
Monaco

NIGERIA/НИГЕРИЯ

Mr. J. A. I. Olowu
Deputy Director
Geological Survey Division
Ministry of Mines and Power
Lagos

NORVEGE/NORWAY/NORUEGA/НОРВЕГИЯ

Professor Leif Störmer*
Institute for Geology
University of Oslo
Blinden, Oslo - 3

Professor Brian A. Sturt
University of Bergen
Bergen - 5000

Professor Frank M. Vokes
University of Trondheim
Trondheim - N. T. K. 7034

NOUVELLE-ZELANDE/NEW ZEALAND/
NUEVA ZELANDIA/НОВАЯ ЗЕЛАНДИЯ

Dr. G. W. Grindley
Chief Project Geologist
N. Z. Geological Survey
Box 30368
Lower Hutt

PAYS-BAS/NETHERLANDS/PAISES BAJOS/
НИДЕРЛАНДЫ

Professeur C. W. Drooger*
Professeur en Chaire
Université d'Utrecht
11, Rue Professeur Wentlaan

Dr. G. L. Krol
Billiton Company
19 L. Couperusplein
La Haye

Mr. B. P. Hageman
Chief, Mapping Department
Service gouvernemental de géologie
17 - Spaarne
Haarlem

POLOGNE/POLAND/POLONIA/ПОЛЬША

Dr A. Jelinski
Vice-Directeur de l'Institut de géologie
Varsovie

Dr S. Cieslinski
Chef de la Division de stratigraphie
Institut de géologie
Varsovie

ROUMANIE/ROMANIA/RUMANIA/РУМЫНИЯ

S. Exc. M. le Professeur V. Ianovici*
Membre de l'Académie
Premier vice-ministre des mines, du
pétrole et de la géologie

S. Exc. M. L'Ambassadeur V. Lipatti,
Délégué permanent auprès de l'Unesco

M. E. Davidescu
Directeur au Département de la géologie
Ministère des mines, du pétrole et
de la géologie
Bucarest

Dr Dan Patrulius
Chef de section à l'Institut géologique
de Bucarest

Dr Hans Kräutner
Chercheur principal à l'Institut géologique
de Bucarest

ROYAUME-UNI/UNITED KINGDOM/REINO UNIDO/СОЕДИНЕННОЕ КОРОЛЕВСТВО

Dr. A. W. Woodland*
Deputy Director
Institute of Geological Sciences
Exhibition Road
South Kensington
London S. W. 7

Professor T. N. George
Professor of Geology
University of Glasgow
Glasgow, Scotland

Mr. N. F. Hughes
University Lecturer
Sedgwick Museum
Cambridge

SUEDE/SWEDEN/SUECIA/ШВЕЦИЯ

Dr. G. Kautsky
Chief of Department
Geological Survey
Stockholm - 50

Professor A. Martinsson
Senior Research Associate
Swedish Natural Science Research Council
University of Uppsala
Uppsala

Professor E. Welin
Director, Mineralogy Department
Natural History Museum
Stockholm - 50

Professor C. G. Wenner
Chairman of the Swedish National
Committee for Geology
University of Stockholm
Stockholm - 50

SUISSE/SWITZERLAND/SUIZA/ШВЕЙЦАРИЯ

Dr. Félix Guilliéron
Adjoint scientifique de la Division de la
science et de la recherche
Département fédéral de l'Intérieur
Berne - 3003

Professeur W. K. Nabholz
Président de la Commission géologique
de Suisse
Institut géologique de l'Université
Berne

REPUBLIQUE-UNIE DE TANZANIE/UNITED REPUBLIC OF TANZANIA/REPUBLICA UNIDA DE TANZANIA/ОБЪЕДИНЕННАЯ РЕСПУБЛИКА ТАНЗАНИЯ

Mr. J. L. Saria
Mineral Resources Division
P. O. Box 903
Dodoma

TCHAD/CHAD/ЧАД

Mr. L. Ortlieb
Chef du Service géologique
Direction des mines et de la géologie
P. O. Box 816
Fort-Lamy

TCHECOSLOVAQUIE/CZECHOSLOVAKIA/CHECOSLOVAQUIA/ЧЕХОСЛОВАКИЯ

Dr V. Zoubek*
Académicien, directeur de l'Institut géologique
Académie des sciences
Praha

Dr V. Bucha
Directeur de l'Institut de géophysique
Académie des sciences
Praha

THAILANDE/THAILAND/TAILANDIA/ТАИЛАНД

Mr. S. Sundharovat
Head, Department of Geology
Faculty of Science
Chulalongkorn University
Bangkok

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Chief, Section of Mineralogy and
Krystallochemistry
Academy of Science
Kiev

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Dr. V. Iarmoluk
Deputy Minister of Geology of the USSR
Geological Institute, Academy of Science
Moscow

Professor V. V. Menner
Academician
Vice-Director, Geological Institute
Academy of Science
Moscow

Professor A. A. Geodekyan
Vice-Director, Institute Oceanography
Academy of Science
Moscow

Dr. V. L. Barsoukov
Institute Geochemistry
Academy of Science
Moscow

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Director of All-Union Geological Institute
Vsegej, Leningrad

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Mrs. C. Petzall
Head, Stratigraphy Department
Geological Survey Division
Dirección de Geología
Ministerio de Minas
Caracas

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Professeur à l'Université d'Hua

YOUGOSLAVIE/YUGOSLAVIA/ЮГОСЛАВИЯ

Dr. Professeur A. Polsak
Professeur à l'Université de Zagreb
Socijal-Revolucije 8/II
Zagreb, Yougvol

Mr. V. Filipovski
Director of the Special Fund for
Geological Research
Skopje, Yougvol

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Dr. R. L. Johnson
Principal Geologist
Geological Survey Department
Lusaka

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Directeur de l'Institut de géologie
à l'Institut catholique de Paris

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Dr. N. M. Shukri
Regional Adviser for Mining and Geology
Economic Commission for Africa

Commission économique pour l'Afrique/Economic Commission for Africa/ Comisión Económica para Africa/Экономическая комиссия для Африки

Dr. N. M. Shukri
Regional Adviser for Mining and Geology

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BRGM, Orléans

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Ecole nationale supérieure
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Professeur J. P. Rothé
Institut de physique du globe
5, rue René Descartes
Strasbourg

4. Commission inter-unions de géodynamique/ Inter-Union Commission on Geodynamics/ Comisión Interinstitucional sobre Geodinámica/Межсоюзная комиссия по геодинамике

Miss F. Delany
Executive Secretary of ICG

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Secrétaire général
Laboratoires de geophysique
Liège

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Trinity College, Dublin

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Université de Nancy
Nancy

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Dr. S. van der Heide

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M. Batisse
Directeur, Division de recherches relatives aux ressources naturelles, SCE
Director, Natural Resources Research Division, SCE

F. Ronner
Secrétaire de la Conférence
Secretary of the Conference

M. Fournier d'Albe
Spécialiste du Programme, Division de recherches relatives aux ressources naturelles, SCE
Programme Specialist, Natural Resources Research Division, SCE

K. Lange
Spécialiste du Programme, Division de recherches relatives aux ressources naturelles, SCE
Programme Specialist, Natural Resources Research Division, SCE

Miss I. Dudeney
Spécialiste du Programme, Division de recherches relatives aux ressources naturelles, SCE
Programme Specialist, Natural Resources Research Division, SCE

Mme L. d'Andigné de Asis
Spécialiste du Programme, Division de recherches relatives aux ressources naturelles, SCE
Programme Specialist, Natural Resources Research Division, SCE

les
ek
ants, Division de recherches relatives aux ressources naturelles, SCE
Consultants, Natural Resources Research Division, SCE